Harvey Water
Water Quality Management Plan and Risk Assessment

Water security and discharge of treated water from Harvey Fresh

Prepared by

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1 Contents

1 Introduction

1.1 Project

Harvey Water is dedicated to the long-term water security and supply of safe non-potable water to its users. Harvey Water has identified the potential to receive 1 megalitre (ML) per day of treated wastewater (TWW) from the nearby Harvey Fresh dairy and Juice processing facility. Provided the adequate treatment and monitoring of treated effluent from Harvey Fresh's wastewater treatment plant (WWTP), Harvey Water is proposing a transfer pipeline to deliver the treated water to the Harvey Dam. The proposed pipeline route and location of the discharge outfall is shown in Figure 1.

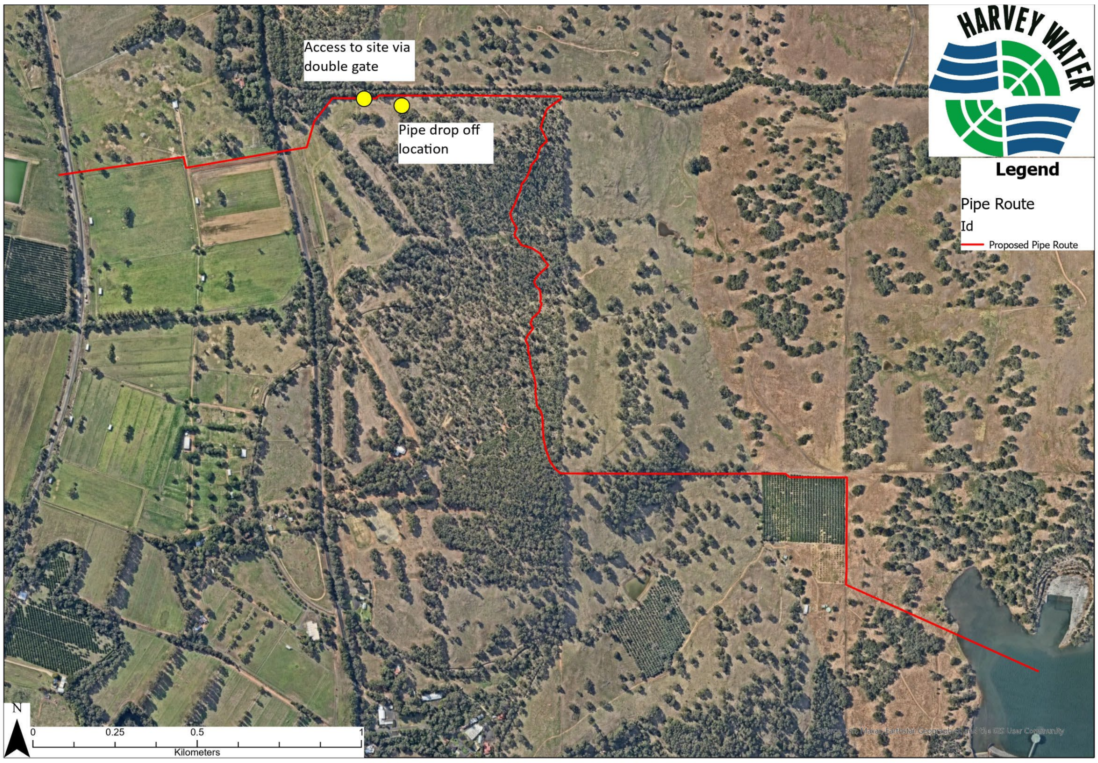


Figure 1 Proposed transfer pipeline route from Harvey Fresh WWTP outlet to the discharge location at Harvey Dam.

1.2 Document Purpose

The following document provides the foundations of a Water Quality Management Plan that adopts the framework set out in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2018) as an adaptive long-term monitoring and management approach to the receival of the TWW resource into the Harvey Dam. This document has been developed to support Harvey Water's works approval and licence application to the Department of Water and Environmental Regulation.

1.3 Approvals Background

Harvey Water has already gained development approval (subject to the attached conditions outlined in Application No. P17.23) from the Shire of Harvey's delegated authority (Delegation No. 9.1.2(1)) for the installation of the proposed pipe to transfer treated wastewater from Harvey Fresh to the Harvey Dam via various properties. The Shire of Harvey has also approved (subject to attached conditions outlined in Application No. P142/23) the application for the proposed ground works and installation of tanks on Lot 200 208 Third street Harvey 6220. Harvey Water has also received written Approval in Principle from the Department of Health for the Harvey Water Wastewater recycling scheme (subject to the conditions set out in F-AA-88785 response from DOH).

2 Existing Environment

2.1 Overall Catchment

The South-West Irrigation Management Co-Operative (SWIMCO), trading as Harvey Water, manages and distributes non-potable water from several water reservoirs to its irrigator members and non-member costumers for use of industrial, mining, construction, hobby farming, garden, fire attenuation and community purposes. Figure 2 outlines Harvey Water's entire operating area and the irrigation districts they service.

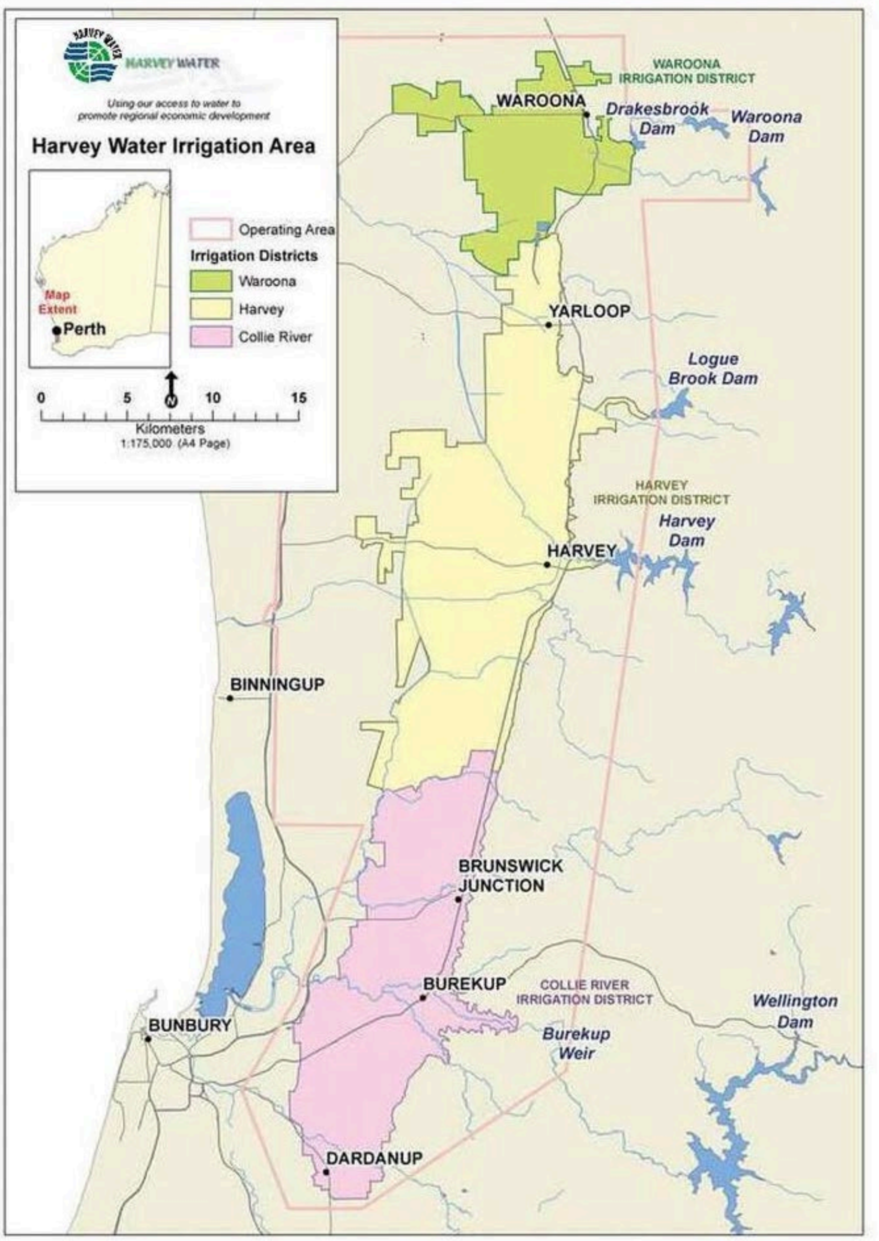


Figure 2 Harvey Water Irrigation Area.

2.2 Harvey Dam

The Harvey Dam reservoir provides the majority of the non-potable water required by the Harvey irrigation district. The Harvey Dam, located within the Shire of Harvey, was originally constructed as a weir in 1916 and subsequently upgraded, with its last major upgrade in 2002, to allow a full storage capacity of 56,000 ML over a water surface area of 553 hectares. The Harvey Dam is situated in a larger catchment area of approximately 126 square kilometres.

CSIRO (2009) predicts through climate modelling that the Harvey region could experience a reduction in mean annual runoff by 7 to 40% by 2030. A reduction in flow and low water levels poses a potential risk and can lead to a number of changes in the aquatic ecosystem, including altered water quality, decreased aquatic habitat, reduced connectivity and restrictive biota passage between habitats. The additional flow from the TWW into the Harvey dam if managed adequately can contribute to reducing this pressure and the risks associated with reduced flows.

Over the last 8 years, the water storage volume has ranged from 10,000 ML in May 2020 (end of irrigation season) to a maximum storage of 53,000 ML in October 2022, equivalent to a water depth range of approximately 20 m to 34 m deep, respectively. Figure 3 shows a yearly comparison of water volume within the reservoir. Typically, water storage increases from May through to October, then declines due to a decrease in rainfall, an increase in evaporation and water usage from Harvey users (including environmental water releases).

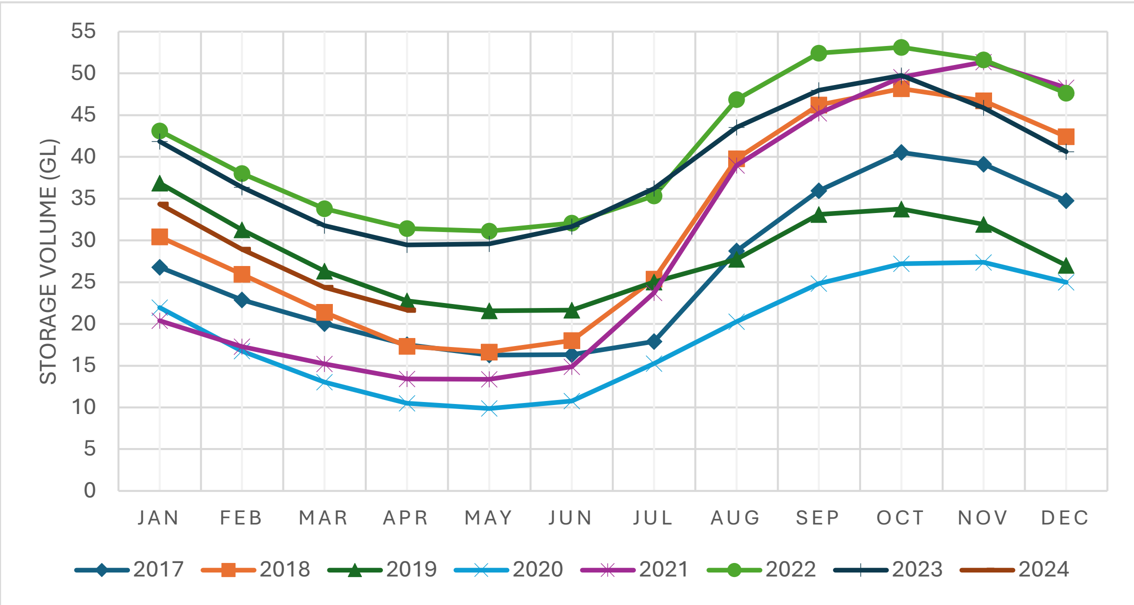


Figure 3 Comparison of Annual water depth for the last 8 years[1].

The average storage fluctuation from May to October is 23 GL, approximately 54% of water turnover per year.

The Harvey Dam is categorised as a level 3 aquatic ecosystem (Lacustrine systems or lakes). These systems are defined by their dominance of open water, characterised by deep, standing, or slow-moving bodies of water that typically exhibit minimal to no emergent vegetation. This category therefore applies to modified systems, such as dams, which have similar characteristics to lacustrine systems.

Cowardin et al. (1979) describe these aquatic ecosystems using the following characteristics:

[1] Source: https://www.watercorporation.com.au/Our-water/Rainfall-and-dams/Dam-levels/Harvey-Dam

- situated in a topographic depression or a dammed river channel,
- sparse vegetation coverage (< 30 % coverage area),
- total area exceeds 8 hectares; and
- depth greater than 2m

The Harvey Dam provides public access for recreational purposes, which include both primary and secondary contact activities.

- Primary contact recreation includes swimming & wading, seasonal recreational fishing (September 1st to June 30th).
- Snaring of marron is also a significant activity during the January/February season attracting large numbers of people.
- Secondary contact recreation includes canoeing and other paddle crafts; however, power boats are not permitted.

Fisheries Western Australia (WA) have engaged in ongoing efforts to release and annually restock marron, as well as both rainbow and brown trout, into Harvey Dam. According to the classification by Fisheries WA, Harvey Dam is designated as a Category 3 – open waters, which suggests that the introduction of trout is anticipated to have minimal impact on the existing ecosystem. This restocking program has been instrumental in establishing a recreational freshwater fishery within Harvey Dam, thereby enhancing its social and economic value.

Smooth marron (*Cherax cainii*) is commonly found and stocked in the Harvey Dam. In General, populations are under pressure from declining range and abundance. Key factors contributing to these pressures include salinisation, habitat degradation, and fishing pressures. Despite these challenges, smooth marron is not currently classified as a vulnerable or threatened species.

Carter's freshwater mussel has been surveyed within the Harvey Dam reservoir and therefore will need to be considered within the WQMP. Carter's freshwater mussel *(Westralunio carteri)* are listed as vulnerable under the *Biodiversity Conservation Act 2016*, and the *Environment Protection and Biodiversity Conservation Act 1999*.

2.3 Harvey Dam Survey

On 3rd January 2024, Smart Subsea deployed divers, and a manned vessel to survey the dam floor, along a 243 m transect, identified by Harvey Water as the potential line to install the outfall pipe and diffuser assembly.

Table 1 Transect line, start and end point, for proposed pipeline and diffuser location.

Transect	Grid position	
Start point	399902E	6339987N
End point	400126E	6339892N

The survey revealed a maximum depth of 21.2 meters in the dam, and a relatively uniform gradient across the dam floor transect Figure 4.

Figure 4 Transect line of the dam floor survey, used for this risk assessment.

The predominant composition of the dam's floor is characterised by a layer of lightly compacted silt, approximately 100-150 mm in thickness, overlaying a solid rock base, with minimal indications of aquatic habitat presence.

Based on these findings, the survey concluded that the installation of the pipeline along the proposed route is feasible. However, it recommended a minor adjustment to the pipeline's path, suggesting a deviation of approximately 5 m towards the north. This adjustment is advised to accommodate the physical characteristics and conditions identified on the dam floor, ensuring optimal placement and installation of the pipeline.

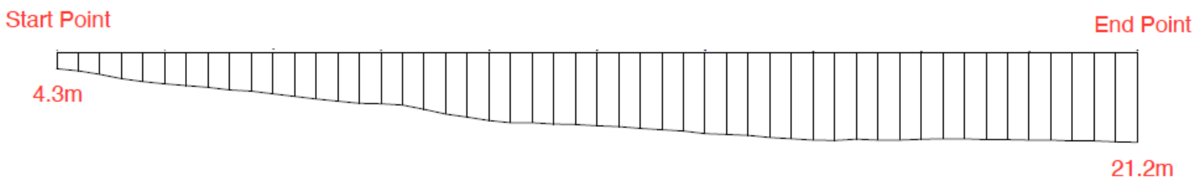


Figure 5 Scaled image of the dam floor gradient along the transect line.

2.4 Discharge Location and Diffuser Design

The proposed discharge pipeline is designed with a diameter of DN180, and a single diffuser positioned 1m beneath the typical baseline water level and approximately 28 m below the water level when at full capacity. This design will enhance mixing efficiency in the initial zone. Additionally, the chosen site for the pipeline ensures sufficient separation from areas designated for recreational uses, minimising potential impacts on these activities. The final design flow rate and velocity of the diffuser are yet to be determined; this information will provide the required data to determine the extent of the mixing zone, if required.

2.5 Harvey Dam Water Quality

Table 2 is an overview of the physical and chemical water quality collected from the sample tap of the Harvey Dam outlet. Water samples are typically taken biannually, and the data covers the period from November 2013 to March 2024. Included are the results from a recent grab sample on 4th September 2023. The ANZECC (2000) default guideline values (DGVs) for inland reservoir waters within the Southwest region of Australia are included as a reference. Where the average ambient water quality is higher than the DGV's 80th percentile trigger values (TV) have been adopted as per the ANZG (2018) slightly to moderately disturbed ecosystem.

Table 2 Mean background nutrient levels in Harvey Dam versus default guideline values.

Parameter	pH	DO	Turbidity	Salinity*	BOD	FRP	TP	NH_4+	NOx	TN
Units		mg/L	NTU	µs/cm (ppm)	mg/L	mg P/L	mg P/L	mg N/L	mg N/L	mg N/L
ANZECC (2000) DGV	6.5-8	>5	10-100	300-1500 (165-825)	15	0.005	0.01	0.01	0.01	0.35
80th percentile TV (2013-2023)				(348)			0.025	0.04	0.344	0.68
Harvey Dam (2013-24)	7.29		3.73	(287)	3.522	0.0064	0.022	0.54	0.18	0.51
Harvey Dam 4th Sep 23 sample	7.8	10	2.4	(250)	2.5	0.0025	0.0025	0.008	0.11	0.36

Dissolved Oxygen (DO), Filterable Reactive Phosphorous (FRP), Total Phosphorous (TP) Ammonia (NH4+) Nitrogen oxides (NOx) and Total Nitrogen (TN)
**Conversion of Electrical Conductivity (us/cm) to TDS (ppm) using 0.55 factor.*

A detailed water sample analysis conducted on 4th September 2023, showed the levels of various contaminants—including pesticides (organochlorine, organophosphorus, and those that are banned), phthalates, industrial hydrocarbons, treatment organics, heavy metals, and metalloids—were all below the 95% species protection limit and 99% species protection limit for toxicants with a bioaccumulating nature or where the ANZG (2018) recommends for protecting key species.

Another sampling campaign on the 8th April 2024 analysed Polycyclic Aromatic Hydrocarbons (PAHs), Polychlorinated Biphenyls (PCBs), Per- and polyfluoroalkyl substances (PFAS), including Perfluorooctanesulfonic (PFOS), Perfluorooctanoic (PFOA), Perfluorohexanesulfonic (PFHxS), Dioxins and Furans. Three sample locations were measured with both samples resulting in measurements for all analytes below the detection limit, set at 99% species protection as per ANZG (2018).

These findings are in compliance with the standards set by the ANZECC & ARMCANZ (2000) and the updated toxicant guidelines provided by Warne et al. (2018). This provides an initial basis for the background concentrations within the Harvey Dam to derive Draft WQOs and management goals.

2.6 Water Source, Quantity and Quality

The Licenced (L4404/1991/15) Harvey Fresh dairy and juice processing facility generates 1 ML/day of wastewater. The wastewater undergoes a high level of treatment via a WWTP located on the Harvey Fresh premise. The proposed daily inflow represents a total annual inflow of 365 ML/day, equivalent to 0.7% of the maximum storage volume (53,130 ML) recorded in October 2022 and 3.6% of the minimum storage volume (9,870 ML) in May 2020. With an average fluctuation in storage volume of 23,389 ML, the annual inflow would represent only 1.5% of the fluctuation volume and 1.2% of the average storage volume (30,595 ML) from 2017 to 2023. The expected dilution of the inflow volume and turnover of reservoir water is adequate to meet regulatory requirements.

Table 3 summarises the Minimum and maximum storage volumes recorded at Harvey Dam from 2017 to 2023 and provides an estimation of daily and annual inflow as a percentage of the storage volume.

Table 3 Comparison of TWW inflow and Minimum and Maximum Storage Volumes recorded at Harvey Dam

Year	Min. Storage Volume (ML/d)	Max. Storage Volume (ML/d)	Fluctuation in Storage Volume (ML/d)	Daily inflow as a % of Min. total volume	Daily inflow as a % of Max. total volume
2017	16,270	40,530	24,260	0.0061%	0.0025%
2018	16,640	48,170	31,530	0.0060%	0.0021%
2019	21,570	33,750	12,180	0.0046%	0.0030%
2020	9,870	27,210	17,340	0.0101%	0.0037%
2021	13,370	49,570	36,200	0.0075%	0.0020%
2022	31,110	53,130	22,020	0.0032%	0.0019%
2023	29,570	49,760	20,190	0.0034%	0.0020%
Average	19,771	43,160	23,389	0.0059%	0.0024%
Annual inflow as a % of avg storage volume	1.8%	0.8%	1.5%		

The Harvey Fresh WWTP encompasses several key components and processes designed to ensure the effective treatment of the wastewater, enabling it to meet regulatory standards and environmental guidelines. The treatment process typically involves the stages outlined in Table 4.

Table 4 Harvey Fresh WWTP treatment process and description

Treatment Process	Description
Preliminary Screening	Rotary screen removes coarse solids.
Equalisation Tank	A 500kL aerated balance tank stores screened wastewater and allows operational control of hydraulic loads through the WWTP, which is vital for stabilising the feed fluctuations that occur during the processing operations.
Dissolved Air Flotation (DAF)	Removal of suspended solids, fats, oils, and greases. Sludge from this process is removed and transferred to a sludge dewatering system.
Sequencing Batch Reactors (SBR)	Two SBR units are used for the removal of organics, nitrogen, and phosphorus compounds via nitrification, denitrification, and biological phosphorus processes. Operational cycles are optimised to manage long term changes and seasonal fluctuations in wastewater loads. Excess sludge is wasted and processed via a sludge thickening system.
Additional Storage	Additional storage is used to satisfy the holding time requirements for disinfection of the wastewater prior to being transferred to Harvey Dam.

Disinfection System	Disinfection is achieved via an ultraviolet disinfection unit followed by a chlorination system that ensures 0.2-2.0 mg/L of free chlorine residual is achieved at the discharge point in Harvey Dam.
Sludge Thickening	Waste sludge from the SBR is thickened in a Huber RoS2s disk thickener increasing solid content from approximately 0.2-0.5% to approximately 2-4% solid content, before being sent to the sludge dewatering system.
Sludge Dewatering	Sludge from both the DAF and thickener is combined and fed into a Huber RoS3 Dewatering Screw Press, where it is dewatered to a solid content of 8-15% prior to off-site disposal.

The design and operation of the WWTP are aligned with best practices and regulatory requirements, ensuring that the wastewater from the Harvey Fresh facility is treated effectively. During the treatment process at the Harvey Fresh WWTP, various chemicals are administered for pH adjustment, nutrient supplementation, and disinfection. These include:

Sulphuric Acid: Applied before the DAF unit for preliminary pH correction.
Sodium Hydroxide: Used for pH adjustment after the DAF process.
Urea and Ammonium Nitrate: Introduced into the SBR to provide nitrogen for microbial processes.
Ferric Chloride: Dosed in the SBR for phosphorus removal and to aid in solids separation.
UV Disinfection: Ensuring compliance in terms of disinfection for a wide range of pathogens.
Sodium Hypochlorite: Utilised for disinfecting the treated effluent before its discharge into the Harvey Dam, maintaining a residual of free Chlorine.

As a note, all the streams originating from the processing and entering the wastewater stream have been considered in this study, ensuring these contaminants are effectively monitored.

2.7 Harvey Fresh Water Quality

Table 5 is an overview of the historical physical and chemical water quality at the sample point of the Harvey Fresh TWW. The ANZECC (2000) DGVs for inland reservoir waters within the Southwest region of Australia and adopted 80th percentile trigger values are included as a reference. Harvey Fresh monitors the WWTP daily to determine the performance of their WWTP and to determine the water quality of the treated effluent, as summarised in Table 5. Data is based on approximately 185 samples from 2018 to 2023.

Table 5 Mean background nutrient levels in Harvey Fresh TWW versus default guideline values.

Parameter	pH	DO	Turbidity	Salinity*	BOD	FRP	TP	NH_4+	NOx	TN
Units		mg/L	NTU	µs/cm (ppm)	mg/L	mg P/L	mg P/L	mg N/L	mg N/L	mg N/L
ANZECC (2000) DGV	6.5-8	>5	10-100	300-1500 (165-825)	15	0.005				
80th percentile Trigger Values (2013-2023)							0.025	0.04	0.344	0.68
Avg SBR Decant (2018-23)	7.65				7.89	0.62	1.61	1.06	6.98	11.78
Harvey Fresh TWW 4th Sep 23 sample	7.8	7.1	3.8	(1500)	21	0.0098	0.33	0.016	1.7	3.3

**Conversion of Electrical Conductivity (us/cm) to TDS (ppm) using 0.55 factor.*

The physical and chemical water quality analyses indicate that salinity, ammonium, nitrogen oxides and total nitrogen are above the ANZECC (2000) DGVs or 80th Percentile trigger values. All other parameters meet the ANZECC (2000) DGVs. Based on dilution modelling it is confirmed the concentration of salinity and nutrients are diluted to a safe level within the Harvey Dam and considered as low risk, achieving the ANZECC (2000) or the 80th Percentile trigger values.

A comprehensive water quality assessment of the SBR Decant at Harvey Fresh WWTP on 4th September 2023 indicates the concentrations of concerning contaminants were all below the 95% species protection limit and 99% species protection limit for toxicants with a bioaccumulating nature or where the ANZG (2018) recommends for protection of key species. However, copper was approximately 4.7x higher than the 95% limit of species protection of 1.4 µg/L, measuring 6.6 µg/L. A list of analyte groups measured for this sample campaign is highlighted in Table 6.

Table 6 List of analyte groups measured on 4th September 2023

Wastewater contaminants	
Organochlorine Pesticides	SCSG Pesticides
Organophosphorus Pesticides	SCSG Treatment Organics
Phthalates	Acid Extractable Low-Level Metals (Arsenic, Beryllium, Lithium, Selenium, Silver)
SCSG Banned Pesticides	Dissolved metals
SCSG Organic Compounds: Industrial Hydrocarbons	Inorganics: nutrients

Another sampling campaign on the 8th April 2024 analysed PAHs, PCBs, PFAS (including PFOS, PFOA, PFHxS), Dioxins and Furans. The sample resulted in all measurements below detection limit, set at 99% species protection as per ANZG (2018). These findings are in compliance with the guideline values and standards set by the ANZECC & ARMCANZ (2000) and the updated toxicant guidelines provided by Warne et al. (2018).

The results from 4th September 2023 and 8th April 2024 demonstrate the bioaccumulating toxicants and persisting contaminants in the wastewater stream and the effectiveness of the Harvey Fresh WWTP in reducing persistent and concerning pollutants to levels that are within environmentally safe limits (except for copper and ammonia) and can be considered as low risk to Harvey Dam ecosystem, as defined by the ANZG (2018). 80th percentile trigger vales have been adopted for copper and ammonium based on the historical ambient Harvey Dam water quality being naturally above the ANZECC (2000) and ANZG (2018) DGVs. The Harvey Dam water quality data is derived from the period 2013-2023.

Analyte	unit	80th percentile trigger value
Ammonium	mg/L	0.04
Copper	mg/L	0.0072

The dilution model indicates that the levels of ammonium and copper in TWW entering Harvey Dam fall below the adopted 80th percentile trigger values, as defined by the ANZG (2018) guidelines. Consequently, the dilution poses a low risk.

3 Water Quality Plan

This Water Quality Management Plan (WQMP) adopts the water quality management framework set out by the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018). Below highlights the key processes and implementation of the framework used to develop this report and highlight the ongoing monitoring and the long-term adaptive management approach to ensuring the protection of the Harvey Dam ecosystem.

3.1 Water Quality Management Framework

The ANZECC (2000) guidelines forms part of Australia's National Water Quality Management Strategy which is aimed at supporting sustainable water management. The ANZECC (2000) guidelines provide a set of tools for assessing and managing ambient water quality in natural and semi-natural water resources including freshwater reservoirs. The ANZG (2018) revised guidelines expand the scope to include a broader range of water quality management issues and a more explicit focus on ecosystem health, as well as new and revised DGVs for toxicants, reflecting updated scientific understanding and methodologies. The expanded guidelines are designed to support various environmental and community values associated with waterbodies, such as aquatic ecosystems, drinking water, primary industries, recreation, and cultural and spiritual values. The ANZG (2018) provides a step-by-step guidance on applying the framework to develop a sufficient water quality management plan Figure 6.

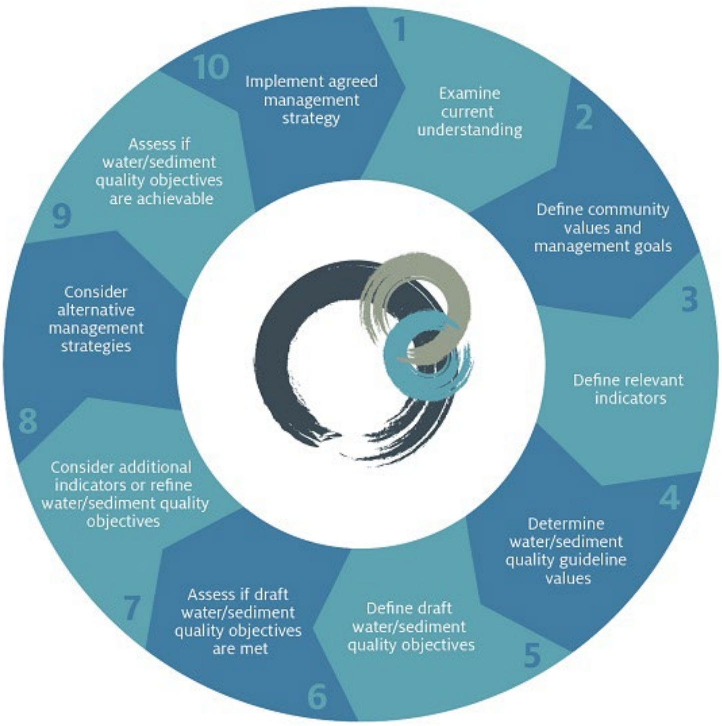


Figure 6 The 10 steps process for implementing the Water Quality Management Framework

The formulation of adequate WQOs is instrumental in guiding the development of management strategies to align with both environmental and community values. Implementing such strategies requires ongoing monitoring, stakeholder engagement, and adaptive management to respond effectively to changing conditions and new information. By prioritising these values and objectives, the management of Harvey Dam can support a sustainable balance between ecological conservation and community needs, ensuring that the dam continues to serve as a vital resource for the region.

3.2 Environmental and Community Values and Draft Objectives

The environmental and community values identified for the Harvey Dam project are outlined in Table 7. A set of WQOs associated with these values has been drafted to guide the management goals and level of protection for the dam's ecosystem, recreational use and safe non-potable water for end users. Table 7 details the interpretation of each WQO. A consideration of the outcomes from community engagement workshops and stakeholder inputs has been integrated into the WQOs. This ensures that the plan is not only aligned with environmental and regulatory requirements but also reflects the values and priorities of the community it serves.

Table 7 Environmental and community values and Draft objectives for the Harvey Dam

Environmental and community Values	Water Quality Objective
Aquatic ecosystem health Refers to both the health and integrity of the ecosystem within the waterway.	**WQO 1** - Maintain the health and integrity of the waterway's ecosystem: Safeguard the health and integrity of the freshwater ecosystem to suitable levels by considering its structure, including biodiversity, biomass, and abundance of biota, as well as its function, such as food chains and nutrient cycles.
Cultural and spiritual Recognises the importance of water and place for indigenous peoples	**WQO 2** - Protect the cultural and spiritual values of the freshwater environment: Preserve the cultural and spiritual values of the indigenous peoples.
Industrial water Refers to waters suitable for industry use	**WQO 3** - Maintain water quality for industrial use: Ensure the water quality is suitable for industrial use.
Primary industries Refers to waters suitable for use in agriculture, irrigation, livestock drinking water, aquaculture and human consumption of aquatic foods.	**WQO 4** - Maintain water quality for primary industry use: Ensure the water quality is suitable for irrigation, livestock drinking water, aquaculture, and consumption of aquatic foods for humans.
Recreation and aesthetics Refers to the activities and importance of the waterway for recreational uses without the risk of sickness or disease or loss of aesthetic appeal.	**WQO 5** - Maintain primary contact recreation values: Ensure it is safe to undertake primary contact activities such as swimming, wading, fishing and marroning.
	WQO 6 -Maintain secondary contact recreation values: Ensure it is safe to undertake secondary contact activities such as canoeing and paddle boarding.
	WQO 7 - Maintain aesthetic values: Protect the aesthetics values

3.3 Ecosystem Condition and Level of Protection

The ANZECC (2000) water quality guidelines identify three main conditions of aquatic ecosystems and recommend the levels of species protection that should be achieved (Table 8). The levels of species protection for which DGVs are typically derived are 99%, 95%, 90%, or 80%, depending on the current or desired ecosystem condition and associated level of protection.

Table 8 Aquatic ecosystem condition and associated level of species protection.

Aquatic ecosystem condition	Level of species protection
High conservation/ecological significance or undisturbed system Systems are considered as undisturbed with resemblance of outstanding/pristine natural and conservation values.	**99% species protection** Where possible there should be no alteration, beyond natural variation, to the chemical and physical properties of water and sediment, including toxicants.
Slightly to moderately disturbed systems Where aquatic biological diversity has been slightly but measurably impacted by human activity, yet the biological communities continue to thrive, and the overall integrity of the ecosystem is largely preserved.	**95% species protection** Allowance for moderate alteration to the chemical and physical properties of water and sediment, including toxicants.
Highly disturbed ecosystems Ecosystems that have undergone measurable degradation and hold lower ecological value.	**80-90% species protection** flexible level of protection and management goals, however, should retain the functionality of the ecosystem and where possible aim to improve the ecosystem condition.

The historical activities and events that are considered to have potentially impacted the ecosystem are:

- The initial construction and upgrade of the dam wall has altered the natural flow regimes.
- Restocking programs (particularly brown and rainbow trout and to some extent marron) alter the natural biodiversity.
- The primary and secondary recreational activities within the reservoir.
- Agricultural development and clearing within the Harvey Dam catchment.

Given the extent of human disturbance, the ecosystem condition is considered as slightly to moderately disturbed and will adopt a 95% species protection or 99% species protection to account for toxicants that have a bioaccumulating nature or where the ANZG (2018) recommends for the protection of key species from acute and chronic toxicity.

Harvey Dam falls within the south-west Australia sub region. The ANZECC (2000) Guidelines has developed default guideline values for physical and chemical stressors in slightly disturbed ecosystem within the Southwest region of Australia. For Freshwater lakes and reservoirs, the following DGV are adopted (see Table 9).

Where background concentrations are naturally above the default guideline values, an 80th percentile has been adopted as site-specific trigger values to compare median data.

The DGV outlined in the ANZECC (2000) guidelines are more stringent than the trigger values set out in the NHMRC (2008) for primary and secondary recreational activities. Therefore, the ANZECC (2000) DGV will be adopted except for where trigger values don't satisfy the minimum requirements set out in the NHMRC (2008).

Table 9 Default guideline values for physical and chemical stressors for slightly disturbed ecosystems in for south-west Australia.

Parameter	pH	Water Temp.	DO	Turbidity	Salinity*	BOD	FRP	TP	NH_4+	NOx	TN
Units			%	NTU	µs/cm (ppm)	mg/L	mg P/L	mg P/L	mg N/L	mg N/L	mg N/L
ANZECC (2000) DGV	6.5-8		>80	10-100	300-1500 (165-825)	15	0.005	0.01	0.01	0.01	0.35
80th percentile Trigger Values								0.025	0.04	0.344	0.68
NHMRC (2008) GV for recreational contact	6.5-8.5	>16 and <34	>80								

**Conversion of Electrical Conductivity (us/cm) to TDS (ppm) using 0.55 factor.*

3.4 Management Goals

Water quality objectives define the qualitative aim and provide a contextual narrative, while management goals establish quantitative measures or statements to assess the ecosystem's health and integrity is being achieved or maintained. The following management goals and level of species protection will aid in achieving the environmental and community values and associated WQOs:

Ongoing ecosystem condition assessment

- Review selected control sites used to relate biodiversity indicators, physical and chemical stressors and toxicants to baseline conditions derived from historical water quality monitoring and future baseline monitoring data.
- review the baseline physical and chemical water quality conditions at selected control sites and determine the relevance of guideline and trigger values.
- Confirm and quantify the key ecosystem receptors and relevant indicators.

Short- and Long-term Goals

- Maintain biological diversity relative to measured conditions at control sites.
- The physical and chemical stressors remain below the derived ANZECC (2000) DGVs for freshwater reservoir systems located in the Southwest Australian region or adopted site-specific trigger values.
- Wastewater toxicant concentrations are below the recommended ANZG (2018) DGVs to achieve 95% species protection and 99% species protection to account for toxicants that have a bioaccumulating nature or were recommended to protect key species from acute and chronic toxicity or adopted site-specific trigger values.
- Long-term salinity levels remain below or within the recommended ranges as per the ANZECC (2000) guidelines for freshwater reservoir systems located in the Southwest Australia.
- Ongoing engagement and review with the community to maintain cultural and spiritual values.

- Recreational and aesthetics of the water quality are below the NRMRC (2008) guidelines for managing risks in recreational freshwater ecosystems.

3.5 Weight of Evidence Assessment

A weight-of-evidence approach is used to gather, analyse, and assess a combination of diverse qualitative, semi-quantitative, and quantitative lines of evidence. This process facilitates a comprehensive evaluation of water and sediment quality, as well as the effectiveness of associated management strategies. Figure 7 depicts the process of using multiple lines of evidence across the Pressure-stressor-ecosystem receptor (PSER) casual pathway. This monitoring program provides adequate data collection to adopt the lines of evidence-based approach to evaluate ecosystem health.

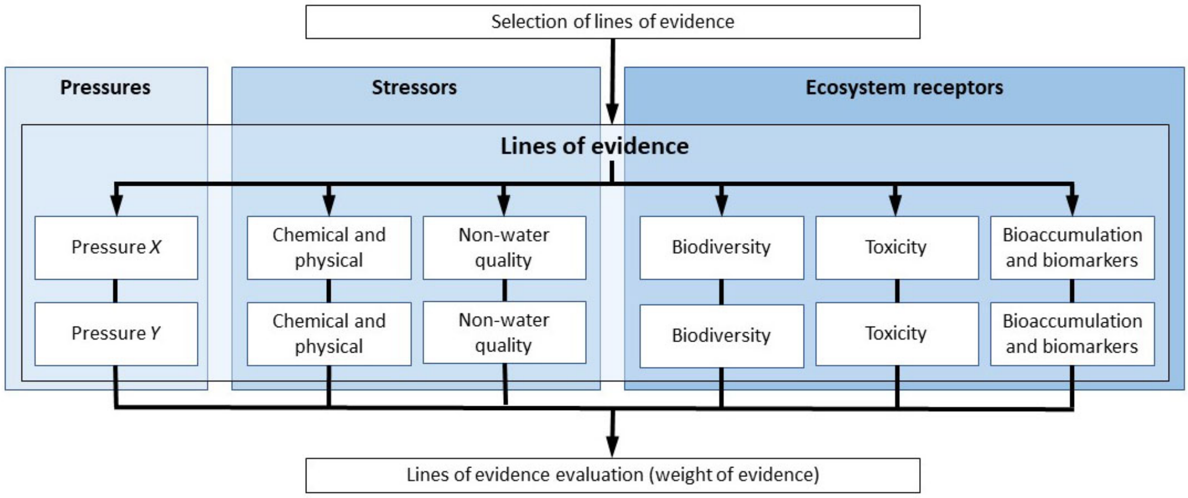


Figure 7 Weight-of-evidence process across the pressure–stressor–ecosystem receptor (PSER) causal pathway

3.6 Pressures

The Harvey Dam presents a unique challenge in water quality management due to its status as a non-confined catchment, exposing it to multiple potential sources of contamination. Its open nature leaves it vulnerable to influences from various land uses, recreational activities, and the risk of uncontrolled spills, among other factors. As such, ongoing monitoring of these potential sources of contamination is imperative to ensure the integrity of the water quality in the dam. By comprehensively assessing and addressing these diverse inputs, we can better safeguard the ecosystem health and sustainability of the Harvey Dam, mitigating risks and preserving its value for both ecological and human use.

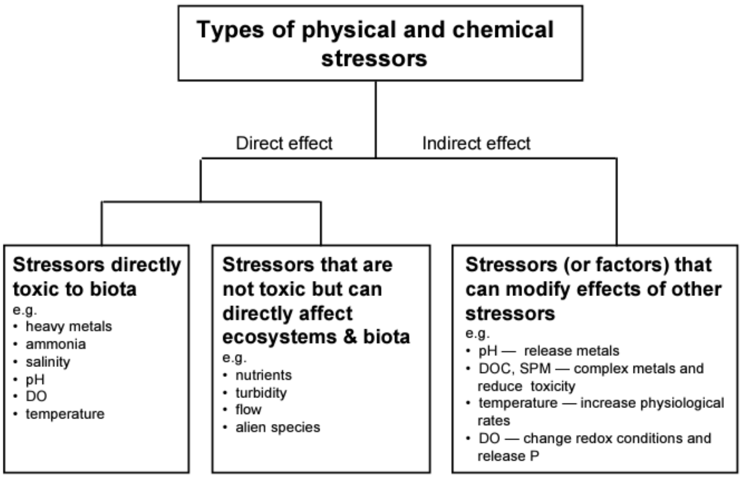
Pressures are described as external activities that drive changes to the ecosystem. The focus pressure on the Harvey Dam identified for the proposed project is the receival of TWW, from the Harvey Fresh Dairy and Juice Processing Facility. The potential environmental impacts of discharging TWW into a dam reservoir are multifaceted and can potentially have a significant effect on water quality, the ecosystem, and water users if not managed adequately. These impacts depend on several factors, including the characteristics of the wastewater, the volume of discharge, the design and operational protocols of the WWTP and dam, as well as the ecological and hydrological characteristics of the reservoir and its effect on downstream users.

The Harvey Dam receives direct stormwater runoff from dam catchments which can introduce additional nutrients. Environmental releases from the Wellington Dam and the Stirling dam could result in additional nutrients, and changes in pH and salinity. Therefore, it is vital to understand the impacts of these sources on the

Harvey Dam ecosystem. Monitoring sites have been selected to identify the natural effects and variations caused from these sources.

3.7 Stressors for Aquatic Ecosystems

Stressors refer to chemical and physical contaminants that can adversely affect the receiving aquatic environment. These stressors can impact biota and ecosystems either directly or indirectly. Indirect stressors are those that can alter the effects of both toxic and non-toxic stressors—for example, a change in pH could lead to the mobilisation of metals. Direct stressors encompass non-toxic factors such as nutrients, chlorophyll a, temperature, and turbidity, as well as toxic substances including heavy metals, ammonia, organic chemicals, and salinity.



Understanding the stressors linked to system pressure/s is essential for devising appropriate measures to monitor and evaluate the system. This knowledge aids in assessing the environmental impacts of the stressors and is crucial for developing effective management strategies to mitigate any adverse effects.

3.7.1 Potential Stressors in Treated Wastewater

3.7.1.1 Alteration of Water Quality

Nutrient Enrichment: Wastewater discharge can introduce high levels of biologically available nutrients such as ammonia, nitrite, nitrate, and orthophosphate into the reservoir. At times, this may stimulate phytoplankton growth beyond natural levels, which can result in harmful algal blooms, which deplete oxygen in the water and can produce toxins harmful to aquatic life and humans.

Chemical Contamination: Wastewater can contain various toxic chemicals, including heavy metals, toxicants in washdown substances, which can accumulate in the aquatic ecosystem, posing risks to aquatic organisms and potentially entering the human food chain. Potential risk to end users using water for irrigation of edible crops and feed stock drinking water.

Stratification: If the wastewater has a significantly different salinity or temperature from the reservoir water, a potential effect can be stratification of the reservoir, affecting aquatic species adapted to specific salinity or temperature ranges. Stratification can also inhibit oxygen transfer between stratified layers resulting in potential hypoxia and risk to aquatic organisms and release of nutrients or metals from the sediment.

3.7.1.2 Impacts on Aquatic Ecosystems

Habitat Alteration: The introduction of pollutants and nutrients can alter the physical and chemical properties of the reservoir, affecting habitat quality for marron, fish and other aquatic organisms. Changes in sediment quality due to the accumulation of salinity, heavy metals and organic contaminants can also impact benthic organisms.

Biodiversity Loss: Elevated levels of nutrients and chemicals can lead to a decrease in species diversity. Sensitive species may decline or disappear, while tolerant species may become dominant, leading to reduced biodiversity.

Food Web Disruptions: Pollutants can affect primary producers (e.g., algae) and primary consumers (e.g., zooplankton), leading to cascading effects throughout the food web. Toxic substances can bioaccumulate in top predators, affecting their reproduction and survival.

Sediment Alteration: Wastewater can further influence sediment dynamics by introducing particulate matter and associated contaminants, affecting sediment quality.

3.7.1.3 Human Health Risks

Waterborne Diseases: Wastewater can contain pathogens that pose direct health risks to humans, especially for primary and secondary recreational purposes and end users.

Bioaccumulation of Toxins: Chemicals and heavy metals from wastewater can bioaccumulate in marron, fish and other aquatic organisms, posing health risks to humans and wildlife consuming these organisms.

3.8 Ecosystem Receptors

Ecosystem receptors are used to assess water quality in freshwater ecosystems by serving as biological indicators, reflecting the impact of stressors on ecosystem functions and services, and informing the development of water quality guidelines. These receptors are integral to understanding the impacts of physical, chemical, and biological stressors on aquatic ecosystems. They serve various roles, from being early-warning indicators that can signal the onset of environmental degradation, to long-term indicators that help assess the ongoing health and stability of ecosystems. In practice, ecosystem receptors are used to derive guideline values for water and sediment quality. These values are based on the sensitivity of the receptors to different stressors and are used to protect ecosystem health by setting limits on stressor concentrations. The importance of understanding the sensitivity and response of various receptors to environmental changes, enables effective monitoring and management of freshwater ecosystems. The following indicators have been identified for this WQMP.

3.8.1 Toxicity

A direct toxicity assessment (DTA) similarly a Whole Effluent Toxicity (WET) test will further evaluate and account for the cumulative impact of multiple toxicants in the TWW. This method allows for the assessment of the combined effects of all contaminants present in the effluent on the receiving environment. This assessment will help reviewing the dilution required for the discharge of TWW into the Harvey Dam. To ensure a high reliability guideline value and determination of an acceptable dilution, chronic toxicity data will be developed for at least 8 species from 4 taxonomic groups (and a good fit of the SSD model).

3.8.2 Biological Indicators

Aquatic macroinvertebrates are widely recognised as effective biological indicators of water quality. Their biological and ecological characteristics make them sensitive to changes in water quality, from the sub organismal to the community level. These organisms exhibit responses to a variety of stressors, including pollution, which can be quantitatively measured to assess the overall health of freshwater ecosystems.

Chlorophyll-a is used as a primary indicator for eutrophication in water monitoring. Chlorophyll-a concentrations are utilised to assess the nutrient status in the water and to monitor the growth of algae, which will indicate the health of the aquatic ecosystem.

Monitoring of intestinal enterococci will aid in assessing the microbiological health of the dam, and particularly for recreational primary and secondary users. Additionally, Naegleria sp., specifically Naegleria fowleri, a free-living amoebic flagellate, will be monitored for its potential to cause amoebic meningoencephalitis in humans.

3.8.3 Biodiversity and Bioindicators of Water Quality

Aquatic macroinvertebrates, in particular, are used as bioindicators of water quality. They serve as a cost-effective and useful tool for monitoring and assessing the ecological status of freshwater ecosystems. The presence, absence, and abundance of certain macroinvertebrate species can indicate the level of water quality and the impact of various stressors such as pollutants.

3.8.4 Bioaccumulation Measures

Refers to the measurement of contaminant accumulation such as metals and organic pollutants within the tissues of aquatic organisms. This method of monitoring, known as bioaccumulation monitoring, provides a time-integrated measure of contaminant levels, which is more representative of long-term exposure. The long-term bioaccumulation effects can be measured using freshwater mussels, marron or fish found within the Harvey Dam.

Bivalves, including mussels, are filter feeders that play a significant role in aquatic ecosystems. They have the ability to process large volumes of water to extract food, which also results in the accumulation of various contaminants present in the water. This characteristic makes them excellent indicators of water quality and environmental health. Bivalves can accumulate pollutants such as heavy metals and organic contaminants within their tissues over time.

Marron also serves as a multifaceted indicator of water quality in freshwater systems through their sensitivity to environmental changes, their ecological roles, and the direct and indirect effects of water quality on their health and populations. Monitoring these aspects can provide valuable insights into the health of freshwater ecosystems. To account for the marron restocking program at the Harvey Dam, monitoring needs to consider the age and size of sampled marron to ensure individuals have been adequately exposed to the water conditions.

Bioaccumulation monitoring will be recommended in the event that water sampling results from the dam show any exceedance to the trigger value.

4 Monitoring Plan

The primary objective of the monitoring plan is to gather ongoing data to assess and ensure the discharge of TWW meets the WQO and to guide management actions.

The data collection encompasses physical, chemical, and biological parameters that are relevant to the identified environmental stressors and indicators. The selected monitoring locations have been strategically chosen, and the consideration of appropriate seasonal timings and sampling frequencies, to capture the natural variability of the ecosystem.

Current water monitoring occurs biannually, typically during the months of January/February and again around September/October. The timing of these monitoring periods captures the seasonal variability of water quality. Grab samples are taken from a sample tap at the bottom of the dam wall or directly from the dam's edge behind the wall (Figure 8), if the sample tap doesn't produce a sample. These samples are collected, preserved, and handled in accordance with the standards outlined in AS/NZS 5667 and analysed by a NATA accredited laboratory. Further details on the extended monitoring sites are provided in Section 4.2.

Figure 8 Approximate sampling locations for Harvey Dam monitoring.

To enhance the available data, the monitoring plan has been extended to five sites. One site near the estimated mixing zone, three control sites, and the dam outlet to provide a better cross reference of the ecosystem conditions and water quality being released.

As new data becomes available, continual review of guideline and trigger values will be undertaken. The ongoing monitoring program will continually be developed to provide relevant ongoing data and decision criteria for the detection in significant variances from baseline and control conditions. A weight of evidence assessment is used to integrate the collected data from different lines of evidence to ensure any changes are detected early and managed appropriately for the long-term ecosystem protection.

This plan is designed to systematically monitor several locations within the proposed discharge area and at specifically chosen control sites. The goals of this monitoring are:

- collection of data, to characterise the water quality, and biological indicators to characterise the ecosystem's conditions, at each control site.
- Confirm water quality of the treated wastewater stream
- Acquire adequate data to model the mixing zone (if required).
- Provide direction for the ongoing monitoring and long-term assessment of WQOs and managements goals.

4.1 Mixing Zone

It is a standard practice to establish a mixing zone, which is considered as a defined area surrounding a discharge site where a temporary reduction in water quality is considered acceptable and WQOs may not be met (ANZECC & ARMCANZ, 2000). Dilution modelling and water quality data confirms adequate dilution will be achieved for toxic contaminants, therefore based on ANZG (2018) guidelines an assessment of the mixing zone may not be necessary.

4.2 Selecting Monitoring Sites

4.2.1 Spatial Boundaries and Scale

The selection and location of sampling sites has been strategically chosen to be representative of the reservoir catchment area and the potential zone of impact, while also providing comprehensive coverage to account for the influence of upstream impacts. At the same time, the plan maintains sufficient resolution to accurately monitor and achieve key water quality objectives.

4.2.2 Harvey Dam – Receiving Environment.

The following monitoring sites have been selected (Figure 9):

- Three control sites, strategically located beyond the potential zone of influence, to serve as control sites of the natural water conditions. All three sites have similar ecological structure to the proposed discharge area. The selection of one upstream site to account for natural variations from environmental flow events and anthropogenic impacts. One site near the existing field sampling site (above the dam wall) to also relate historical data. A site on the northern bank opposite the field sampling site (>400m from dam wall) will capture effects, from a prevailing southwest wind, on surface waters, located northeast of the proposed discharge location.
- monitoring of the area near the proposed discharge location.
- The ongoing monitoring of the sample tap located at the bottom of the dam wall to relate historical data.
- All sites are recorded using a GPS unit to record the coordinates of the selected sites to ensure future samples are taken in the same location.

Figure 9 Approximate location of monitoring sites. Green = proposed discharge site, Blue = Dam outlet sample tap and Orange = 3 control sites.

4.2.3 Harvey Fresh – Wastewater Source

The monitoring and sampling of the TWW occurs at the outlet of the Harvey Fresh WWTP, in accordance with the procedures outlined in the Harvey Fresh Recycled Water Quality Management Plan (RWQMP). These activities are carried out by trained operators from Harvey Fresh.

4.2.4 Weather Station Data

Climate data for Western Australia is accessed via BOM. The closest weather station is Harvey, operated by Harvey Water, coordinates 115.9E / 33.1S. . A cross check of climate data using the average extrapolated data from SILO grid points, latitude: -33.10, Longitude: 115.95 and latitude: -33.05, Longitude: 115.95.

4.3 Sampling and Monitoring

The following outlines the sampling and monitoring approach that is being implemented and follows the protocols set out in the Australian and New Zealand water quality standards (AS/NZS 5667 series).

Time-of-day measurements are considered for physical parameters that are affected by photosynthesis and respiration. A set start time will be followed for each sampling campaign and the same order of site sampling to minimise the impact of these conditions on results.

4.3.1 Harvey Dam

4.3.1.1 Field Monitoring

Due to the deeper waters within the reservoir, vertical profiling provides a better understanding of how well mixed the water column is or indicates if stratification is occurring. A multi-parameter sonde is used to measure depth, salinity, pH, water temperature, redox potential, turbidity and dissolved oxygen. At each monitoring site, measurements are from the bottom to the surface. Once bottom depth is taken, measures at ~0.5 m increments are taken until the surface, stopping at each increment until a stabilised reading is measured, each measurement is logged and recorded. Post-sampling, recorded data will be downloaded from the device onto a laptop and stored for analysis. A field sampling sheet will be used to record site details, measurements and observations.

4.3.1.2 Water Quality Grab Samples

A surface water sample will be collected at each site, from a depth of 0.5m below the water surface, aligning with the EPA (2017) guidelines. The specified sampling depth ensures consistency with established protocols for monitoring water quality, providing a representative analysis of the aquatic environment at a level that is influenced by light penetration, temperature variations, and biological activity. This approach aids in achieving accurate and relevant data for assessing the water's condition and ensuring compliance with environmental standards.

During each sample campaign one of the monitoring sites will randomly be selected, to split the collected sample into two bottles (field split sample) and one additional sample (field replicate) for QA/QC purposes. The aim of the field split sample is to determine the magnitude of error in analytical procedures. The field split sample will provide a percentage difference between two samples at the same site. The replicate sample is used to detect the variation due to field sampling methods and natural variations in the ecosystem.

All samples will be submitted and analysed at the same time by a NATA approved laboratory. The suitable analytical methods for the analytes summarised in Table 10, below, will be determined in consultation with the chosen laboratory.

4.3.1.3 Biological and Biodiversity Sample

The Australian River Assessment System (AusRivAS) protocol for macroinvertebrate monitoring is a standardised approach used across Australia to assess the ecological condition of rivers. This protocol involves the collection and analysis of benthic macroinvertebrate samples to evaluate ecosystem health.

4.3.2 Harvey Fresh WWTP

4.3.2.1 Water Quality and Testing

Grab samples are taken from the outlet of the Harvey Fresh WWTP as outlined in the Harvey Fresh RWQMP. The list of analytes measured are outlined in Table 10

Additionally, continuous online monitoring is available and measures pH, temperature and residual chlorine at the outlet of the disinfection system and at the Harvey Fresh discharge point.

4.4 Sampling Frequency

Monthly field monitoring and water sampling are planned for the first 6 months after initial discharge and if water quality objectives are continuously met, a reduction in monitoring to a quarterly basis will continue. Quarterly monitoring will focus on the key seasonal periods that the Dam water is used to ensure the WQOs are met. This approach ensures that the data adequately reflects the natural variability and supports effective management and protection of the water body's ecological health and its users. Sample frequency will be reviewed at the end of each year in the annual report and adapted as necessary. If a non-compliance occurs, then monthly monitoring will be resumed until two consecutive samples return compliant results.

4.5 Measurements Analysis

All samples will be sent to a NATA accredited Laboratory for analysis.

The following parameters have been selected and are derived on results from historical water quality data, from the sampling campaigns on the 4th September 2023 and 8th May 2024, potential contamination of the TWW from the Harvey Fresh processing facility and their importance to the potential impact on the reservoir ecosystem, recreational safety, and end users. Parameters include:

Table 10 Water sample analytes for all grab water samples and adopted trigger values

Analyte Group	Analyte	Unit	PQL	Adopted Trigger Values	Source and Level of Species Protection (LOSP)
Acid Extractable	Antimony	µg/L	1	9	ANZG (2018) DGV toxicants unknown LOSP
	Arsenic	µg/L	1	24 (as III) and 13 (as V)	ANZECC (2000) - Aquatic ecosystems slightly–moderately disturbed systems; 95% LOSP
	Beryllium	µg/L	0.5	100	ANZECC (2000) Primary industries
	Lithium	µg/L	1	75	ANZECC (2000) Primary industries
	Selenium, Total	µg/L	1	5	ANZG (2018) DGV toxicants 99% LOSP
	Silver	µg/L	1	0.05	ANZECC (2000) - Aquatic ecosystems slightly–moderately disturbed systems; 95% LOSP
Dissolved Metals	Sulphur	mg/L	0.5		
	Silica	mg/L	0.2		
Dissolved Low Level	Aluminium	µg/L	10	55 (pH>6.5)	ANZECC (2000) - Aquatic ecosystems slightly–moderately disturbed systems; 95% LOSP
	Barium	µg/L	1		
	Boron	µg/L	20	370	ANZECC (2000) - Aquatic ecosystems slightly–moderately disturbed systems; 95% LOSP

	Cadmium	µg/L	0.1	0.2	ANZECC (2000) - Aquatic ecosystems slightly–moderately disturbed systems; 95% LOSP
	Chromium	µg/L	1	1	ANZECC (2000) - Aquatic ecosystems slightly–moderately disturbed systems; 95% LOSP
	Cobalt	µg/L	1	1.4	ANZG (2018) DGV toxicants unknown LOSP
	Copper	µg/L	1	7.2	Site specific 80th Percentile Trigger Value
	Iron	µg/L	10	0.27	Site specific 80th Percentile Trigger Value
	Lead	µg/L	1	3.4	ANZECC (2000) - Aquatic ecosystems slightly–moderately disturbed systems; 95% LOSP
	Manganese	µg/L	1	1900	ANZECC (2000) - Aquatic ecosystems slightly–moderately disturbed systems; 95% LOSP
	Mercury	µg/L	0.05	0.06	ANZECC (2000) - Aquatic ecosystems slightly–moderately disturbed systems; 99% LOSP
	Molybdenum	µg/L	1	34	ANZG (2018) DGV toxicants unknown LOSP
	Nickel	µg/L	1	11	ANZECC (2000) - Aquatic ecosystems slightly–moderately disturbed systems; 95% LOSP
	Strontium	µg/L	1		
	Titanium	µg/L	1		
	Uranium	µg/L	1	0.5	ANZG (2018) DGV toxicants unknown LOSP
	Vanadium	µg/L	1	6	ANZG (2018) DGV toxicants 95%LOSP
	Zinc	µg/L	1	8	ANZECC (2000) - Aquatic ecosystems slightly–moderately disturbed systems; 95% LOSP
Inorganics - Physical Parameters	pH	pH units		6.5-8.5	ANZECC (2000) – Freshwater reservoir aquatic ecosystems in south west region of Australia
	Electrical Conductivity	µs/cm		1500	ANZECC (2000) – Freshwater reservoir aquatic ecosystems in south west region of Australia
	Total Dissolved Solids	mg/L	5	825	ANZECC (2000) – Freshwater reservoir aquatic ecosystems in south west region of Australia
	Total Suspended Solids	mg/L	5	<40	ANZECC (2000) – Freshwater reservoir aquatic ecosystems in south west region of Australia
	Turbidity	NTU	0.1	10	ANZECC (2000) – Freshwater reservoir aquatic ecosystems in south west region of Australia
	Dissolved Oxygen	mg/L	0.1	>5	ANZECC (2000) – Freshwater reservoir aquatic ecosystems in south west region of Australia
	Colour (True)	PCU	5	30	ANZECC (2000) – Freshwater reservoir aquatic ecosystems in south west region of Australia
Inorganics - Ionic Balance and Indexes	Bicarbonate Alkalinity as CaCO3	mg/L as CaCO3	5		
	Carbonate Alkalinity as CaCO3	mg/L as CaCO3	5		
	Hydroxide OH- as CaCO3	mg/L as CaCO3	5		
	Total Alkalinity as CaCO3	mg/L as CaCO3	5	>20	ANZECC (2000) – Freshwater reservoir aquatic ecosystems in south west region of Australia
	Chloride	mg/L	1	<175 for sensitive crops	ANZECC (2000) Primary industries
	Sulphate	mg/L	1		
	Calcium	mg/L	0.5		
	Magnesium	mg/L	0.5	15	ANZECC (2000) – Freshwater reservoir aquatic ecosystems in south west region of Australia
	Potassium	mg/L	0.5		
	Sodium	mg/L	0.5	<115 for sensitive crops	ANZECC (2000) Primary industries

	Hardness as CaCO3	mg/L	3		
Inorganics - Organic Carbons	Total Organic Carbon	mg/L	1		
	Dissolved Organic Carbon	mg/L	1		
Inorganics - Nutrients	Ammonia as N	mg/L	0.005	0.9	ANZG (2018) DGV toxicants 95%LOSP
	Free Ammonia (unionised) as N by calculation	mg/L	0.007		
	Ammonium (NH4+) as N by calculation	mg/L		0.04	Site specific 80th Percentile Trigger Value
	Nitrate as N	mg/L	0.005		
	Nitrate as NO3 by calculation	mg/L	0.02		
	Nitrite as N	mg/L	0.005		
	Nitrite as NO2 by calculation	mg/L	0.02		
	NOx as N	mg/L	0.005	0.344	Site specific 80th Percentile Trigger Value
	TKN as N by calculation	mg/L	0.1		
	Organic Nitrogen by calc.	mg/L	0.1		
	Total Nitrogen	mg/L	0.1	0.68	Site specific 80th Percentile Trigger Value
	Phosphate as P	mg/L	0.005	0.025	Site specific 80th Percentile Trigger Value
	Reactive Silica	mg/L	0.1		
	Chlorophyll-a	mg/m3	1	5	ANZECC (2000) – Freshwater reservoir aquatic ecosystems in south west region of Australia
Inorganics - Common	BOD	mg/L	5	15	ANZECC (2000) – Freshwater reservoir aquatic ecosystems in south west region of Australia
	COD	mg O2/L	20	40	ANZECC (2000) – Freshwater reservoir aquatic ecosystems in south west region of Australia
Microbiological Suite	Thermotolerant Coliforms	cfu/100mL	1		
	E.coli	cfu/100mL	1	13	Site specific 80th Percentile Trigger Value is lower than the recommended GV of 35 cfu/100ml as per NHMRC (2008) - Guidelines for Managing Risks in Recreational Water
Amoebae	Thermophilic Amoebae	per 250mL	1	1	ADWG Health Value
	Thermophilic Naegleria	per 250mL	1	1	ADWG Health Value

4.6 Assessment

Collected data will be used to characterise and assess the treated wastewater and ecosystem conditions, against adopted guideline and trigger values. The assessment will evaluate if WQOs are met and identify non-compliances and if there is any short- and long-term variations of the ecosystem conditions. A predictive modelling tool is employed to forecast long-term water quality in Harvey Dam and assess the impact of TWW on the system. This tool offers both short- and long-term outlooks, aiding proactive management decisions. To enhance accuracy, the model will be updated every five years with new datasets for fine-tuning and calibration.

4.7 Reporting

Harvey Water's reporting strategy encompasses several key elements to ensure comprehensive and timely communication of ecosystem conditions, water quality results, management goals, and regulatory compliance. Here's a detailed breakdown:

1. Alignment with Internal Protocols and Regularity Obligations: Reporting will adhere to Harvey Water's established internal protocols and regulatory obligations. This ensures consistency and compliance with industry standards and legal requirements.

2. Ecosystem Characterisation of Harvey Dam: The report will provide a detailed overview of the ecosystem conditions surrounding the Harvey Dam. This includes factors such as biodiversity, habitat health, and any changes or trends observed over time.

3. Water Quality Results: Comprehensive water quality data will be included in the report. This may encompass parameters such as pH, dissolved oxygen levels, nutrient concentrations, and presence of pollutants or contaminants.

4. Water Quality Objectives (WQO) and Management Goals: The report will outline the water quality objectives established for the Harvey Dam and associated management goals. This provides a framework for assessing the effectiveness of management strategies in maintaining or improving water quality.

5. Guideline Values or Criteria for Assessing WQO: Clear guidelines will be provided for assessing compliance with water quality objectives. This may involve comparison against established guideline values or criteria for various parameters.

6. Recommendations for Ongoing Monitoring: Based on the analysis of current data and trends, recommendations will be made for ongoing monitoring efforts. This ensures that data collection remains relevant and sufficient for assessing water quality and ecosystem health.

7. Adaptations to Monitoring Plan: If necessary, the report will propose adaptations to the monitoring plan to address emerging issues or changes in regulatory requirements. This flexibility ensures that monitoring efforts remain effective and responsive to evolving conditions.

8. Updates to Water Quality Management Plan (WQMP): Any updates or revisions to the Water Quality Management Plan will be documented in the report. This ensures that management strategies are informed by the latest data and insights.

4.7.1 Proposed Reporting Frequency

- Biannual Reports: Detailed reports will be produced every six months over a two-year period. These reports provide regular updates on ecosystem conditions and water quality trends.

- Annual Reports: Following the initial two-year period, reports will be produced annually, unless noncompliance issues arise.

- Five-Year Review: The monitoring model and management strategies will be reviewed every five years to assess their resilience to climate change impacts and to incorporate any necessary adjustments, considering Climate Change uncertainties.

By following this reporting strategy, Harvey Water can effectively monitor and manage the water quality of the Harvey Dam while ensuring compliance with regulatory requirements and adapting to changing environmental conditions.

5 Impact assessment

5.1 Data collection

The data utilised for modelling in the Harvey Fresh treated water recycling project was provided by Harvey Water, encompassing a comprehensive dataset spanning a decade from 2013 to 2023. This dataset included 58 distinct parameters, offering a robust basis for accurate and reliable modelling. The extensive range of parameters ensured that the models could comprehensively assess the environmental impacts, efficiency, and sustainability of the recycling processes proposed. This depth and breadth of data were critical in enabling precise predictions and informed decision-making throughout the project's planning and implementation phases.

In addition to the historical data, we also received current water quality information pertaining to the TWW at Harvey Fresh. Importantly, this dataset did not include data reflecting the most recent upgrades in terms of disinfection processes. This exclusion is significant as it provides a baseline against which the impact of the new disinfection technologies can be assessed. Understanding the pre-upgrade quality of the water helps in evaluating the efficacy and necessity of the latest enhancements, thereby aiding in the continuous improvement of water treatment practices at Harvey Fresh. The summary of the water quality data is presented in Table 11.

Table 11 Summary of the water quality data, including the Harvey DAM historic data, Harvey DAM recent data, Harvey Fresh treated water and adopted Trigger Values (2013-2023).

		Average WQ (2013-2024)	Water Quality (2024)		Trigger Value	Dilution Model Predicted concentration at end of		
Parameter	**Units**	**Harvey Dam**	**Harvey DAM**	**Treated Water**		**2024**	**2029**	**2034**
Copper	mg/L	0.0050	0.0005	0.0066	0.0072	0.0006	0.0007	0.0007
Iron	mg/L	0.1667	0.0240	0.4400	0.2700	0.0277	0.0332	0.0332
TDS	mg/L	287	250	1500	852*	273	300	300
NH4+- N	mg/L	0.0543	0.008	0.016	0.04	0.0085	0.0090	0.0090
NOx - N	mg/L	0.1809	0.11	1.7	0.344	0.1252	0.1476	0.1476
Total Nitrogen	mg/L	0.5155	0.36	3.3	0.68	0.3984	0.4492	0.4489
TP	mg/L	0.0217	0.0025	0.33	0.025	0.0043	0.0077	0.0078
BOD	mg/L	3.5	2.5	21.0	15*	2.8	3.1	3.1
E.coli	cfu/100mL	5.9	8.0	24.0	13	8.6	9.2	9.2

Based on TV adopted in Table 10

5.2 Water Quality Impact Modelling

Figure 10 illustrates the schematic depiction of the Water and Mass Balance framework adopted as the foundational structure for the water quality model, incorporating pertinent symbology. This framework encompasses various components such as rainfall, additional water sources, evaporation processes, extractions, and the integration of Harvey fresh recycled water.

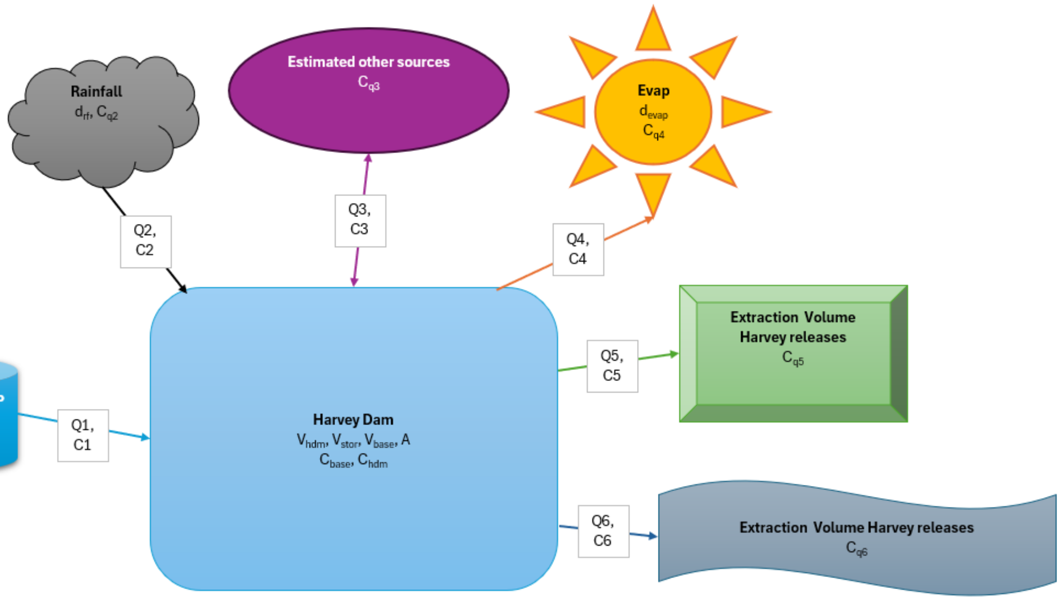


Figure 10 Schematic of Water and Mass Balance used as a basis for the modelling.

In assessing the impact of introducing Harvey Fresh TWW into Harvey Dam, a detailed modelling approach was adopted to estimate the concentrations of critical parameters, including Total Dissolved Solids (TDS), nitrogen, copper, and phosphorous. These parameters were selected due to their significant ecological and health implications for aquatic life and water quality. The models simulate the dispersion and accumulation of these substances within the dam to predict potential changes in water chemistry and ensure that concentrations remain within environmentally safe levels. By using this targeted modelling approach, we aim to establish a robust framework for monitoring and managing the quality of water in Harvey Dam, ensuring it meets both current and future regulatory and environmental standards.

Table 12 summarises the List of assumptions used in the water quality modelling.

Table 12 List of assumptions used in the water quality modelling.

		Units	Source and assumptions
Q_{wwtp}	Constant daily flow of treated wastewater	ML/day	Assumed constant daily outflow from Harvey Fresh WWTP = 1ML/day
Q1	Monthly inflow of treated Water from Harvey Fresh	ML/month	Calculated volume discharged into the Harvey Dam each month
Q2	Rainfall	ML/month	Assumed a constant total internal dam area at the maximum storage volume.
Q3	Estimated Other sources	ML/month	Estimated from a known monthly change in storage volume.
Q4	Evaporation	ML/month	Assumed a constant total internal dam area at the maximum storage volume.
Q5	Extraction Volume - Harvey Release	ML/month	Data provided by Harvey Water. An average monthly extraction volume was calculated from January 2022 to December 2023
Q6	Extraction Volume - Environmental release	ML/month	Data provided by Harvey Water. An average monthly extraction volume was calculated from January 2022 to December 2023
V_{hdm}	Monthly Storage Volume in Harvey Dam	ML	Calculated storage volume in Harvey Dam at the end of each month
d_{rf}	Average Rainfall depth per day	mm/day	Data retrieved from SILO monthly rainfall data download from 2013 to 2023. Calculated an average daily rainfall for each month using following equation: d_{rf} = average monthly rainfall from 2013-2023 ÷ t
d_{evap}	Average Evaporation depth per day	mm/day	Data retrieved from SILO monthly evaporation data download from 2013 to 2023.Calculated an average daily rainfall for each month using following equation: d_{evap} = average monthly evaporation (2013-2023)÷ t
A	Harvey Dam internal area	m^2	Data provided by Harvey Water. Assumed a constant dam internal area, using the estimated area at full capacity. Assumed all rainfall landing in this area would runoff directly into the dam without loss. This is considered as a conservative value for evaporation as it increases the evaporation volumes over the length of the model. Dam internal area = 554,000 m^2
t	total days in month	day	Calculated based on the number of days in each month. Accounted for extra day in every leap year.
V_{stor}	average monthly change in storage volume	ML	Data retrieved from Water Corporation. Average monthly change in storage volume from January 2017 to end of April 2024
V_{base}	Initial storage volume in Harvey Dam	ML	Data retrieved from Water Corporation. Known monthly storage volume at end of August 2023 = 47,990 ML
C_{hdm}	Mass Load of selected contaminant in Harvey Dam	Kg	Calculated mass load in Harvey Dam at the end of each month
C1	Calculated monthly mass load of selected contaminant into Harvey Dam from the treated wastewater	Kg/month	Data provided by Harvey Water. Assumed no variations in water quality therefore a constant concentration value was adopted
C2	Calculated monthly mass load of selected contaminant into Harvey Dam from Rainfall	Kg/month	Assumed no contaminant load associated with rainfall
C3	Calculated monthly mass load of selected contaminant into Harvey Dam from Estimated Other sources	Kg/month	Data provided by Harvey Water. Assumed no variations in water quality therefore a constant concentration value was adopted
C4	Calculated monthly mass load of selected contaminant into Harvey Dam from Evaporation	Kg/month	Assumed no contaminant reduction associated with evaporated water
C5	Calculated monthly mass load of selected contaminant into Harvey Dam from Extraction Volume - Harvey Release	Kg/month	Data provided by Harvey Water. An average concentration was calculated from water quality data from 2013 to 2024.

C6	Calculated monthly mass load of selected contaminant into Harvey Dam from Extraction Volume - Environmental release	Kg/month	Data provided by Harvey Water. An average concentration was calculated from water quality data from 2013 to 2024.
C_{base}	Initial Concentration in Harvey Dam	mg/L	Data retrieved from Harvey Water. Known water quality data at date
Cq1	Concentration of contaminant in the treated wastewater	mg/L	Data provided by Harvey Water. An average concentration was calculated from water quality data from 2013 to 2024.
Cq2	Concentration of contaminant in rainfall	mg/L	Assumed no contamination in rainfall
Cq3	Concentration of contaminant in estimated other sources	mg/L	Assumed no variation of concentration in estimated other sources. Adopted the C_{db}
Cq4	Concentration of contaminant in the evaporation	mg/L	Assumed no loss of contamination in evaporated water
Cq5	Concentration of contaminant in the Extraction Volume - Harvey Release	mg/L	Concentration was calculated using the results of the modelled concentration (Cf) in the Harvey Dam at the end of the previous month.
Cq6	Concentration of contaminant in the Extraction Volume - Environmental release	mg/L	Concentration was calculated using the results of the modelled concentration (Cf) in the Harvey Dam at the end of the previous month.
Cf	Concentration of contaminant in the Harvey Dam reservoir	mg/L	Modelled concentration in Harvey Dam at the end of each month

5.2.1 Water Balance Calculations

A conceptual forecasting model has been developed based off the balance concept and incorporating the proceeding equations to estimate a water and mass balances for various contaminants. This model uses quantitative predictions to determine water sources/sinks, contaminant reductions and loads, and the dilution and accumulation of contaminants within the Harvey Dam reservoir. The predictions are aimed at long-term forecasting (30 years) to provide management with valuable information and guidance for developing effective management strategies. This tool will be reviewed and updated with new data on a 5 yearly bases to recalibrate the model and provide adaptive measures for improved long-term forecasting.

In order to capture seasonal change in rainfall and evaporation, a “monthly” time step was selected for the model.

The equation used to calculate the total storage volume after the first month (September 2023) was calculated using a baseline value derived from the known storage volume at end of August 2023 using the below equation:

$V_{hdm} = V_{base} + Q1 + Q2 + Q3 - Q4 - Q5 - Q6$

Subsequent monthly storage volume was calculated using the calculated storage volume from the previous month:

$V_{hdm} = V_{hdm-1} + Q1 + Q2 + Q3 - Q4 - Q5 - Q6$

The following equations were used to calculate the monthly volume of each stream:

$Q1 = Q_{wwtp} \times t$

$Q2 = d_{rf} \times A \times t$

$Q3 = Q4+Q5+Q6-Q1+Vstor$

$Q4 = d_{evap} \times A \times t$

Q5= {direct data input}

Q6= {direct data input}

5.2.2 Mass Balance

The following equations were used to determine the mass balance for each identified contaminant with elevated concentrations. This cross check is to ensure there is a low risk associated with discharging treated wastewater from Harvey Fresh's WWTP into the Harvey Dam. The model assumes the system is well mixed and does not account for degradation effects.

The calculated mass load for each input and output was calculated using the below equations

$C1 = (Cq1 \div 1{,}000{,}000) \times (Q1 \div 1{,}000{,}000)$

$C2 = (Cq2 \div 1{,}000{,}000) \times (Q2 \div 1{,}000{,}000)$

$C3 = (Cq3 \div 1{,}000{,}000) \times (Q3 \div 1{,}000{,}000)$

$C4 = (Cq4 \div 1{,}000{,}000) \times (Q4 \div 1{,}000{,}000)$

$C5 = (Cq5 \div 1{,}000{,}000) \times (Q5 \div 1{,}000{,}000)$

$C6 = (Cq6 \div 1{,}000{,}000) \times (Q6 \div 1{,}000{,}000)$

The monthly mass balance was calculated using the

The equation used to calculate the mass balance after the first month (September 2023) was calculated using a baseline value derived from the known ambient water quality concentrations in the Harvey dam at end of August 2023 using the below equation:

$C_{hdm} = (C_{base} \div 1{,}000{,}000) \times (V_{base} \times 1{,}000{,}000)$

Subsequent monthly storage volume was calculated using the calculated storage volume from the previous month:

$C_{hdm} = C_{hdm-1} + C1 + C2 + C3 - C4 - C5 - C6$

Final concentration in the Harvey Dam reservoir was calculated using the following equation:

$Cf = (C_{hdm} \times 1{,}000{,}000) \div (V_{hdm} \times 1{,}000{,}000)$

5.3 Modelling Plots

The modelling plots presented below provide detailed insights into crucial parameters within the water system along the next 30 years. Initially, the water balance model indicates a consistent decrease in storage volume, with the baseline level of 2507 ML expected to be breached by May 2047. Dilution modelling for ammonium and Nitrogen Oxides indicates compliance with the adopted 80th percentile trigger values of 0.04 mg/L and 0.344 mg/L, respectively. However, Total Nitrogen dilution modelling suggests potential non-compliance by May 2044, nearing the 80th percentile trigger value of 0.68 mg/L. Conversely, Total Phosphorous dilution modelling predicts one potential non-compliance event by May 2047, with a trigger value of 0.025 mg/L. Total Dissolved Solids modelling indicates compliance with the 80th percentile trigger value of 825 ppm. Biological Oxygen Demand modelling aligns with regulatory standards, with no risk of non-compliance against the ANZECC (2000) Default Guideline Value for freshwater reservoir systems. Dilution modelling for Iron and Copper similarly indicates compliance, with their respective 80th percentile trigger values of 0.27 mg/L and 0.0072 mg/L remaining within acceptable limits.

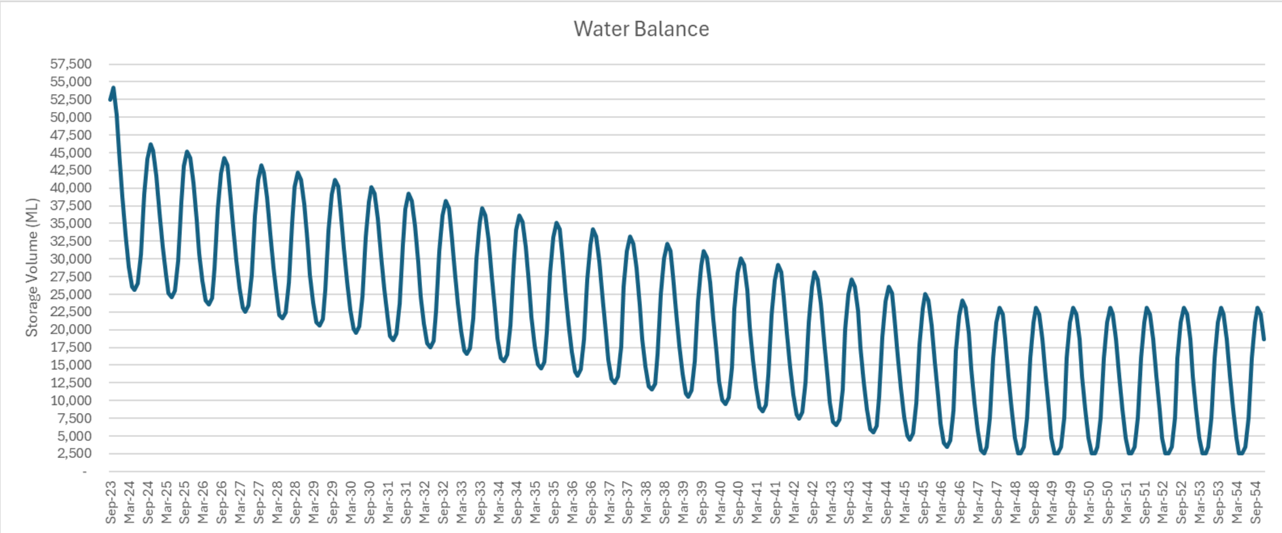


Figure 11 The water balance model indicates a constant decline in storage volume over time with the baseline storage water level of 2507 ML being breached in May 2047.

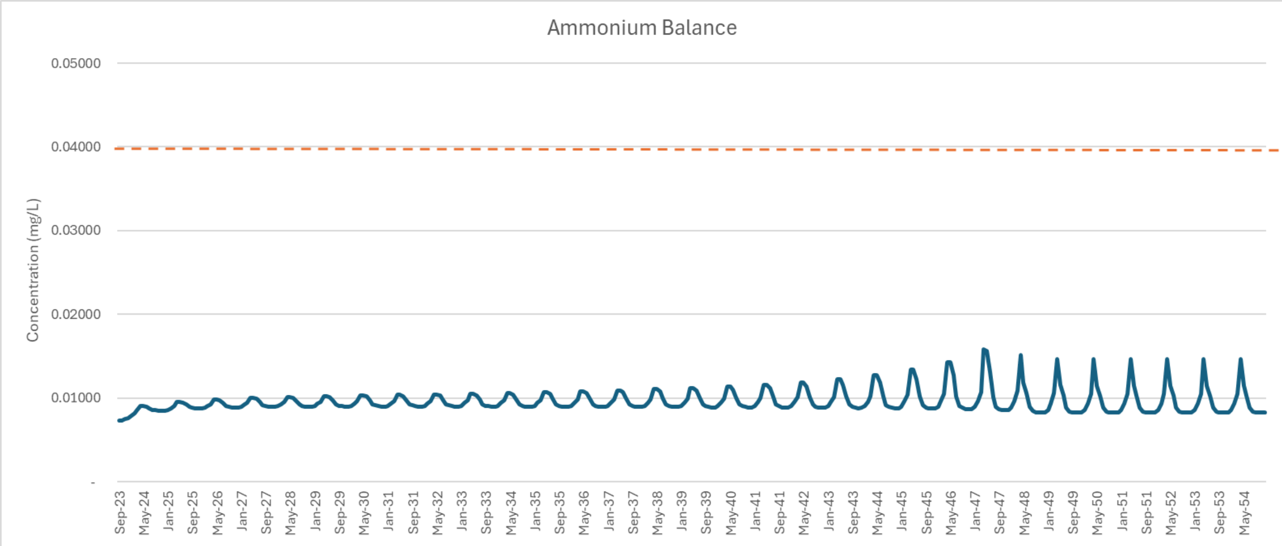


Figure 12 The dilution modelling for ammonium indicates there will be no risk of a non-compliance, based on the adopted 80th percentile trigger value 0.04mg/L

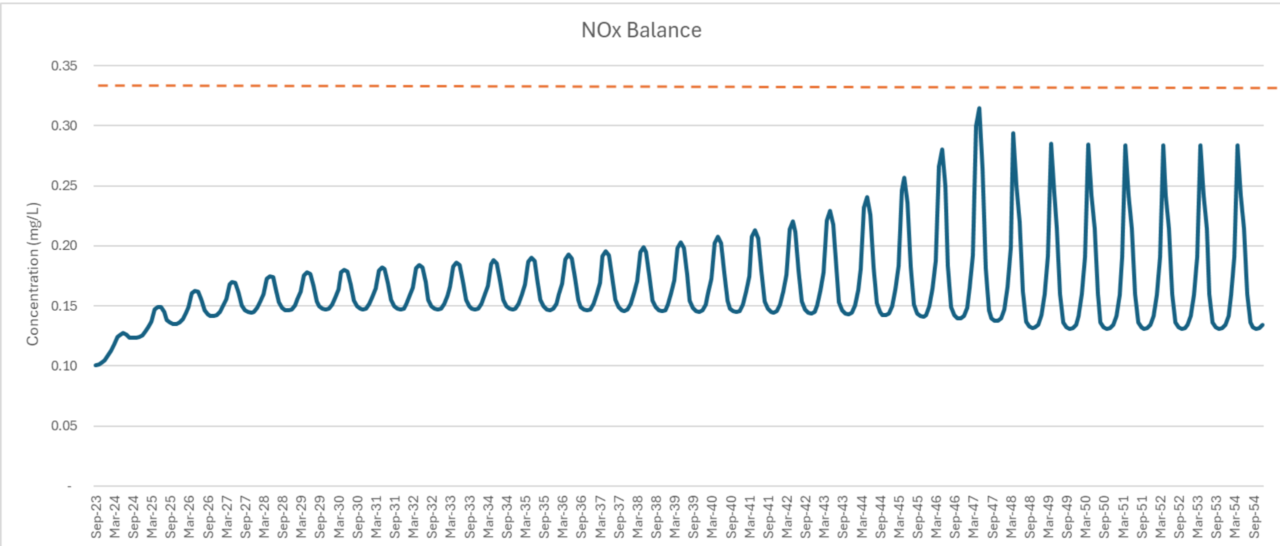


Figure 13 The dilution modelling for Nitrogen Oxides indicates there will be no risk of a non-compliance, based on the adopted 80th percentile trigger value 0.344 mg/L

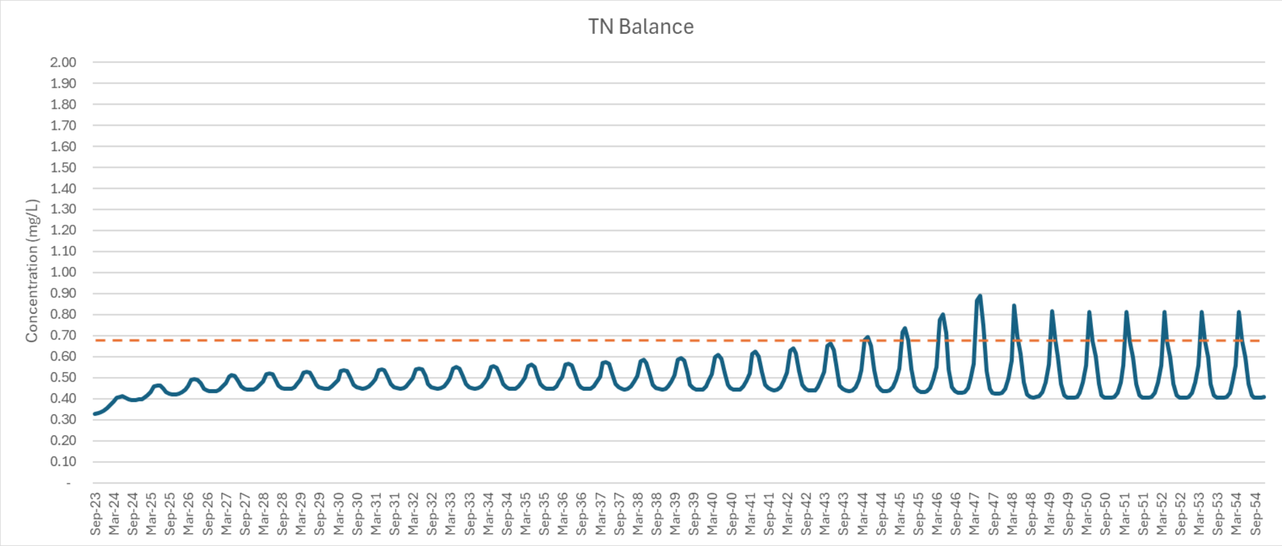


Figure 14 The dilution modelling for Total Nitrogen predicts a non-compliance may occur in May 2044, based on the adopted 80th percentile trigger value 0.68 mg/L

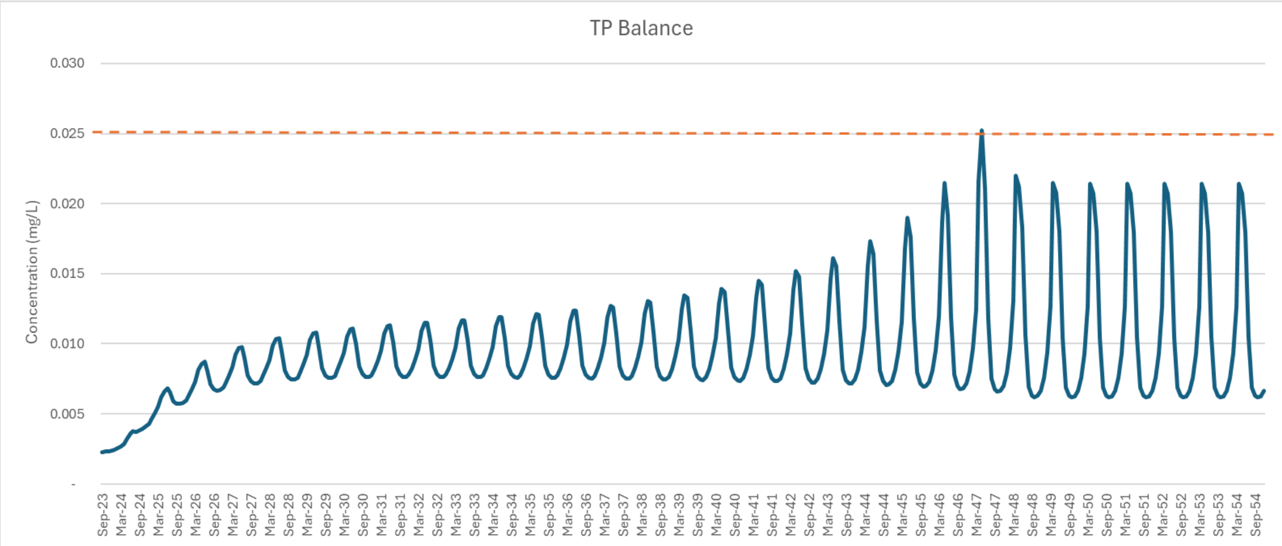


Figure 15 The dilution modelling for Total Phosphorous predicts only one potential non-compliance may occur in May 2047, based on the adopted 80th percentile trigger value 0.025 mg/L

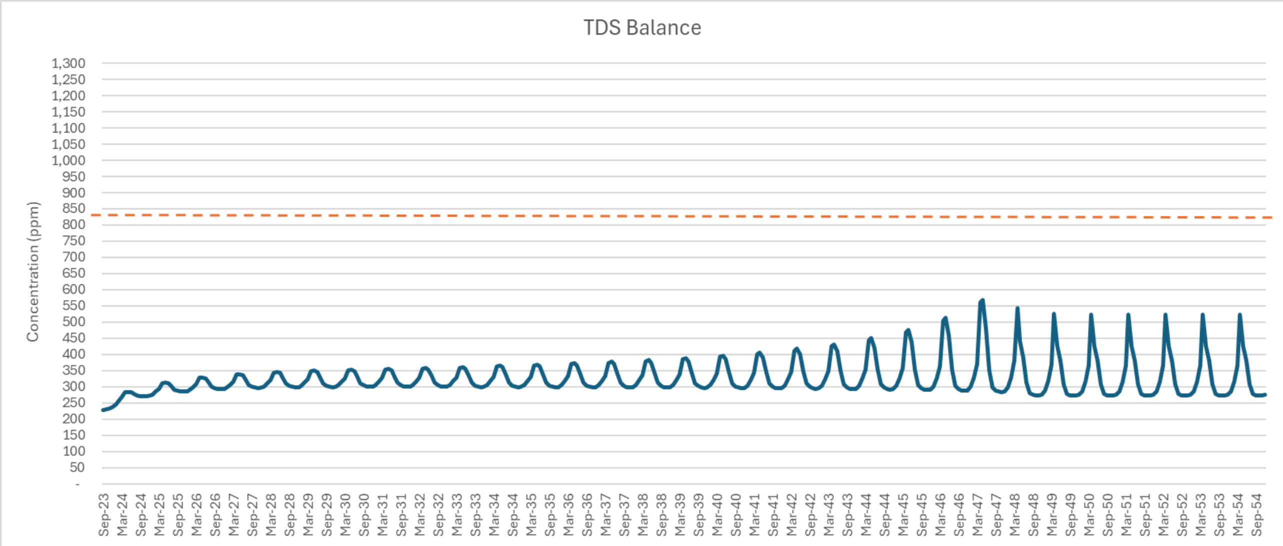


Figure 16 The dilution modelling for Total Dissolved Solids indicates there will be no risk of a non-compliance, based on the adopted 80th percentile trigger value 825 ppm.

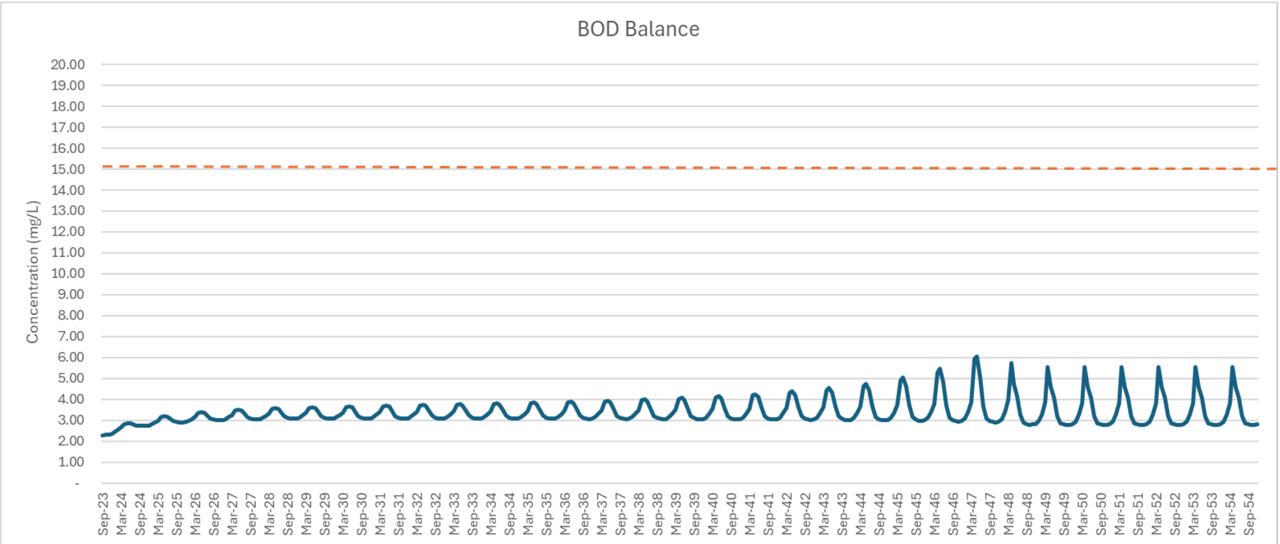


Figure 17 The dilution modelling for Biological Oxygen Demand indicates there will be no risk of a non-compliance, based on the adopted ANZECC (2000) Default Guideline Value for freshwater reservoir systems within the South West Australian region = 15 mg/L

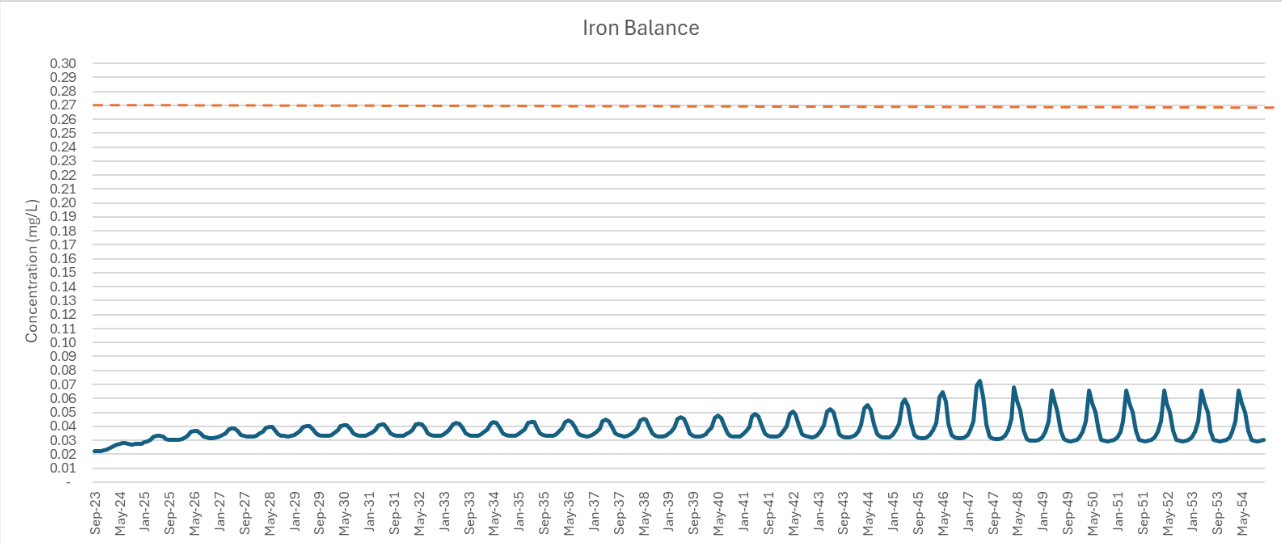


Figure 18 The dilution modelling for Iron indicates there will be no risk of a non-compliance, based on the adopted 80th percentile trigger value 0.27 mg/L

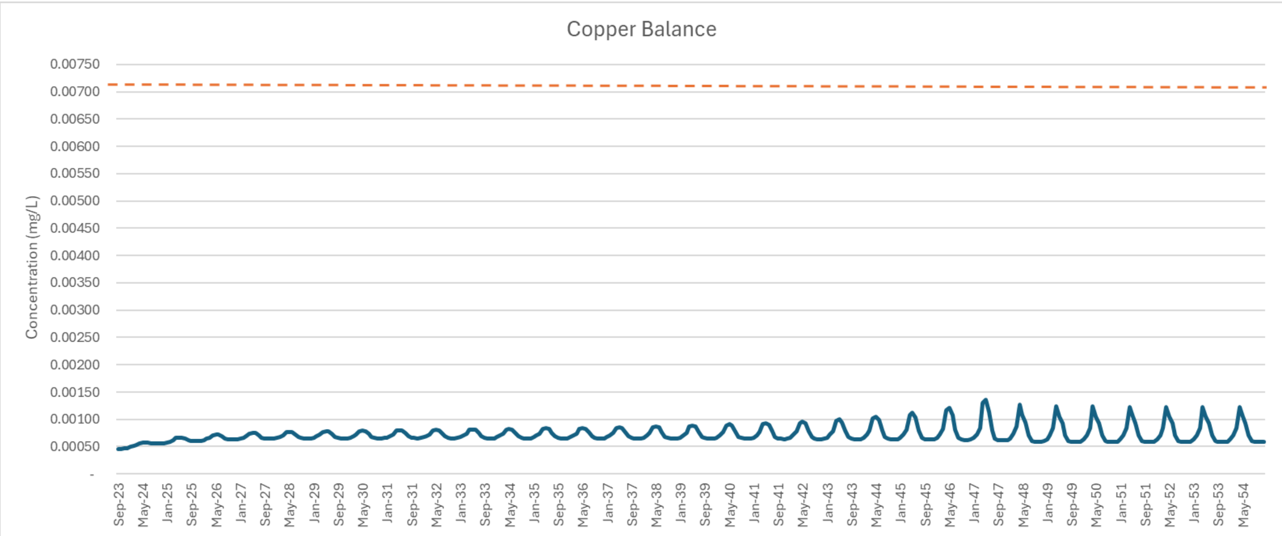


Figure 19 The dilution modelling for copper indicates there will be no risk of a non-compliance, based on the adopted 80th percentile trigger value 0.0072 mg/L

5.4 Risk Analysis

The risk analysis of introducing Harvey Fresh treated wastewater into Harvey Dam considers several critical factors to ensure environmental safety and compliance with regulatory standards. Preliminary data analysis indicates that all measured parameters in the treated wastewater fall below the adopted default guideline value as outlined in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018) or the calculated 80th percentile trigger values. This finding suggests that the treated wastewater is well within acceptable limits for environmental discharge, reducing potential risks associated with water quality. This baseline assessment forms a solid foundation for a comprehensive evaluation of the implications of integrating treated wastewater into Harvey Dam's existing aquatic system. Table 13 presents the Summary of the parameters of concern and the risk management strategy (control).

Table 13 Summary of the parameters of concern and the risk management strategy (control).

Parameter	Trigger Value mg/L	Risk	Time	Control	Residual risk[2]
Ammonium – NH_3/NH_4^+	0.04	No risk	30 years	Not required	Low
Nitrogen Oxides - NOx	0.344	No risk	30 years	Not required	Low
Total Nitrogen - TN	0.68	Non-compliance may occur in May 2044	20 years	Improve biological process by reducing Nitrogen dosing and increasing aeration	Low
Total Phosphorous - TP	0.025	One non-compliance may occur in May 2047	23 years	Incorporate chemical precipitation of Phosphorous	Low
BOD_5	15	No Risk	30 years	Not required	Low
TDS	825	No Risk	30 years	Not required	Low
Copper	0.0072	No risk	30 years	Not required	Low
Iron	0.27	No Risk	30 years	Not required	Low

According to the predictive model, reducing the TP concentration at the outlet of the Harvey Fresh WWTP by 9% ensures compliance for the next 30 years. However, even with an 80% reduction in TN concentration, the model predicts potential non-compliance in April 2047 and recurring annually each April thereafter. Moreover, even with a 100% reduction in TN concentration (TN = 0 mg/L in TWW), the model forecasts non-compliance in May 2047.

[2] Risk assessment according https://www.commerce.wa.gov.au/atom/4207

This limitation arises from the water balance dynamics. The downward trend in storage volume at Harvey Dam is projected to reach the baseline storage level of 2507 ML in May 2047. At this point, the model assumes a constant minimum volume until the storage exceeds 2507 ML. Given the natural ambient water quality and the declining water levels at Harvey Dam, non-compliance appears inevitable under these conditions. To improve accuracy, it's recommended to update the model data every five years to ensure appropriate model calibration.

5.5 Stakeholder engagement

Harvey Water conducted an extensive community consultation process for the Harvey Fresh treated water recycling project, ensuring thorough stakeholder engagement and transparency. This process comprised three critical community meetings on the 12th of July, 19th of September, and 9th of October, 2023, which ran concurrently with specific consultations involving the Harvey Aboriginal Corporation. These parallel consultations were crucial in securing the endorsement of local Indigenous stakeholders, who confirmed that the project was in alignment with their spiritual values.

An independent review was integral to the consultation strategy, evaluating the feedback and potential impacts associated with the project. This independent assessment ensured that the concerns and suggestions from both the broader community and the Indigenous consultations were objectively addressed. The Harvey Water team was proactive in responding to all issues raised, implementing modifications to the project where necessary. This approach not only adhered to best practices in stakeholder engagement but also reinforced the project's commitment to respecting cultural sensitivities and environmental stewardship, thereby enhancing its legitimacy and support within the community.

6 References

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